DOCUMENT RESUME

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IDENTIFIERS	Military Curriculum Project

ABSTRACT

This plan of instruction, study guides, and workbooks for a secondary-postsecondary-level course in refrigeration and air conditioning are one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. It is the second section of a three-part course (see Note for other sections) intended to train students in identification, location, function, installation, operational checking, servicing, repair, and maintenance or refrigeration and air conditioning systems. Dealing specifically with basic refrigeration, refrigeration controls and accessories, and domestic and commercial refrigeration, this section contains three blocks covering 230 hours of instruction: Basic Refrigeration (4 lessons), Refrigeration Controls and Accessories (3 lessons), and Domestic and Commercial Refrigeration (2 lessons). The plan of instruction contains an outline of the teaching steps, criterion objectives, lesson duration, correlation of tasks with a training standard, and support materials and guidance. Student materials include four study guides with text information, objectives, review exercises, and references and four workbooks with performance exercises. Commercial texts, military technical manuals, and audiovisual aids are suggested, but not provided. Materials may be adapted for individualized instruction or presented in a group setting. (YLB)

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CE 024 392

Drafting
Dietetics
Diesel Repair
Dental Assisting
Data Processing
Curriculum Development
Construction Trades
Carpentry
Blueprint Reading
Aviation Mechanics
Auto Mechanics
Welding
Stenography
Small Equipment Repair
Radiology
Radio-TV Broadcasting
Printing
Physical Therapy Assisting
Photography
Patternmaking
Nursing
Medical Lab Assisting
Machine Shop
Management & Supervision
Air Conditioning
Food Service
Electronics
Electricity

Military Curricula for Vocational & Technical Education

REFRIGERATION AND AIR CONDITIONING SPECIALIST

BLOCKS III, VI, & V

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

This military technical training course has been selected and adapted by The Center for Vocational Education for "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education," a project sponsored by the Bureau of Occupational and Adult Education, U.S. Department of Health, Education, and Welfare.

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

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- Developing educational programs and products
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- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

REFRIGERATION AND AIR CONDITIONING SPECIALIST, BLOCKS III, IV, & V

Classroom Course

Developed by:

United States Air Force

Development and Review Dates

September 25, 1974

Occupational Area:

Heating and Air Conditioning

Target Audiences:

Grades 11-adult

Print Pages:

365

Cost:

$7.60

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials:						Instructional Design:				Type of Instruction:	
	Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Group Instruction:	Individualized:
			No. of pages									
Block III – *Basic Refrigeration*			39					★				
Principles of Refrigeration	●		●	★	●	★	●		●	★	●	
Principles of Refrigeration Condensers, Receivers, Evaporators and Compressors	●		●		●	★	●		●	★	●	
Simple Refrigeration Systems	●		●		●	★	●		●	★	●	
Compressor Checks and Trouble Analysis	●		●		●	★	●		●	★	●	
Block IV – *Refrigeration Controls and Accessories*			38					★				
Refrigerant Controls	●		●		●	★	●		●	★	●	
Motor Circuits	●		●		●	★	●		●	★	●	
Refrigeration Accessories and Trouble Analysis	●		●		●	★	●		●	★	●	
Block V – *Domestic and Commercial Refrigeration*			46									
Domestic Units	●		●		●	★	●		●	★	●	
Commercial Units	●		●		●	★	●		●	★	●	

★ Materials are recommended but not provided.

THE CENTER FOR VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

Expires July 1, 1978

Course Description

This is the second section of a three-part course on refrigeration and air conditioning. The course trains students in identification, location, function, installation, operational checking, servicing, repair and maintenance of refrigeration and air conditioning systems. This section deals with basic refrigeration, refrigeration controls and accessories, and domestic and commercial refrigeration. It contains three blocks covering 230 hours of instruction. Students should complete **Refrigeration and Air Conditioning, Blocks I and II** (11-6), before beginning this second part of the course.

Block III — *Basic Refrigeration* has four lessons containing 76 hours of instruction. The lesson topics and respective hours follow:

- Principles of Refrigeration (20 hours)
- Principles of Refrigeration Condensers, Receivers, Evaporators, and Compressors (18 hours)
- Simple Refrigeration System (16 hours)
- Compressor Checks and Trouble Analysis (22 hours)

Block IV — *Refrigeration Controls and Accessories* contains three lessons covering 78 hours of instruction.

- Refrigerant Controls (24 hours)
- Motor Controls (21 hours)
- Refrigeration Accessories and Trouble Analysis (33 hours)

Block V — *Domestic and Commercial Refrigeration* has two lessons containing 76 hours of instruction.

- Domestic Units (46 hours)
- Commercial Units (30 hours)

This section contains both teacher and student materials. Printed instructor materials include a plan of instruction detailing the teaching steps by units of instruction, criterion objectives, the duration of the lessons, correlation of tasks with a training standard, and support materials and guidance. Student materials include four study guides with text information, objectives, review exercises and references; and four workbooks with performance exercises.

Text information is provided in the student study guides, however, several commercial texts and military technical manuals are referenced. Audiovisual aids suggested for use in the entire course include 15 films, 29 transparency sets and 29 charts. The materials in this section can be adapted for individualized instruction or presented in a group setting for courses on refrigeration, air conditioning, and/or heating.

REFRIGERATION & AIR CONDITIONING SPECIALIST

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- Refrigeration Controls & Accessories - Study Guides — Page 118
- Refrigeration Controls & Accessories - Workbooks — Page 178

Block V - Domestic & Commercial Refrigeration

- Plan of Instruction /Lesson Plans — Page 216
- Domestic Units - Study Guide — Page 224
- Domestic Units - Workbooks — Page 272
- Commercial Units - Study Guide — Page 297
- Commercial Units - Workbook — Page 333

CE 029 312

POI 3ABR54530
(PDS Code ATA)

PLAN OF INSTRUCTION

(Technical Training)

REFRIGERATION AND AIR CONDITIONING SPECIALIST

AIR TRAINING COMMAND

SHEPPARD TECHNICAL TRAINING CENTER

16 January 1976–Effective 17 March 1976 with class 760317

11-7

* See underscore in para 1 of Foreword, page i

DEPARTMENT OF THE AIR FORCE
USAF School of Applied Aerospace Sciences (ATC)
Sheppard Air Force Base, Texas 76311

PLAN OF INSTRUCTION 3ABR54530
(PDS Code ATA)
16 January 1976

FOREWORD

1. PURPOSE: This publication is the plan of instruction (POI) when the pages shown on page A are bound into a single document. The POI prescribes the qualitative requirements for Course Number 3ABR54530, Refrigeration and Air Conditioning Specialist, in terms of criterion objectives and teaching steps presented by units of instruction and shows duration, correlation with the training standard, and support materials and guidance. When separated into units of instruction, it becomes Part I of the lesson plan. This POI was developed under the provisions of ATCR 50-5, Instructional System Development, and ATCR 52-7, Plans of Instruction and Lesson Plans.

2. COURSE DESIGN/DESCRIPTION. The instructional design for this course is Group/Lock Step. The course trains airmen to perform duties prescribed in AFM 39-1 for Refrigeration and Air Conditioning Specialists, AFSC 54530. Training includes the use of AF publications and forms, and commercial manuals related to identification, location, function, installation, operational checking, servicing, repair and maintenance of refrigeration and air conditioning systems. The course also includes water analysis and conditioning. In addition, related training is provided on driver education, troop information program, commander's call/briefings, etc.

3. TRAINING EQUIPMENT. The number shown in parentheses after equipment listed as Training Equipment under SUPPORT MATERIALS AND GUIDANCE is the planned number of students assigned to each equipment unit.

4. REFERENCES. This plan of instruction is based on Specialty Training Standard, 54530/50/70, 18 April 1973, and Course Chart 3ABR54530, 15 January 1976.

FOR THE COMMANDER

LEONARD A. HAMILTON, Col, USAF
Chief, Dept of Civil Engineering Training

Supersedes Plan of Instruction 3ABR54530, 15 August 1973
OPR: Department of Civil Engineering Training
DISTRIBUTION: Listed on page A

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER III	BLOCK TITLE Basic Refrigeration

1. COURSE CONTENT	2. TIME
1. Principles of Refrigeration	20 (15/5) Days 16 thru 18
a. Using workbook and equipment provided, determine the amount of heat required to change the state of a substance at atmospheric pressure. STS: 11a, 11b, 11c, 11d, 11e, 11f, 11g, 11h, 11i. Meas: W	(6/2) Day 16

(1) Basic structure of matter

- (a) Definition of matter
- (b) States of matter
- (c) Changes in the states of matter

(2) Basic law of heat flow and transfer

- (a) Methods of heat transfer
- (b) British thermal unit

(3) Principles of heat

- (a) Types of heat and latent heat terminology

(4) Gas laws and the effects of changes in pressure, volume and temperature

- (a) Definition of pressure and vacuum
- (b) Gages and their use
- (c) Boyles law

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(d) Charles law

(e) Dalton's law

(f) Thermodynamics

b. Using workbook and assortment of colored pencils, trace the refrigerant flow for normal operation of the schematic of a simple refrigeration system. STS: 12a, 12c, 12d, 14a. Meas: W (6/2) Day 17

(1) Definition of refrigeration

(2) Major components of a refrigeration system

(3) Positions of compressor service valves

(4) Identification and use of the manifold gage assembly

(5) Characteristics of Halo-Carbon refrigerants

(6) Pressure-Temperature Relationship chart

c. Using refrigerant transfer trainer and tools provided, transfer refrigerant from the storage cylinder into the service cylinder, to the specification in the workbook. Observe all safety precautions. STS: 12b Meas: W, PC (3/1) Day 18

(1) Safety procedures when handling refrigerant and refrigerant cylinders

(2) Calculate by weight the amount of refrigerant contained in a cylinder

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-III-1, Principles of Refrigeration
WB 3ABR54530-III-1-P1, Freezing and Boiling Temperatures of Liquids
WB 3ABR54530-III-1-P2, Measurement of Heat and Temperature
WB 3ABR54530-III-1-P3, Sensible Heat, Latent Heat, and Change of State
WB 3ABR54530-III-1-P4, Identification of Refrigeration System Components
WB 3ABR54530-III-1-P5, Transferring Refrigerant

Audio Visual Aids
Charts, Set, Refrigeration System
Transparencies, Set, Heat Content of Water
Training Film: TF5536a, Refrigeration - Principles of Mechanical Refrigeration Systems
Prenarrated Slide: ATS 54-18, Modified Principles of Refrigeration

Training Equipment
Trainer, Refrigeration Service Valve (12)
Trainer, Manifold Gauge Assembly (12)
Trainer, Simple Refrigeration System (12)
Trainer, Refrigeration Transferring (12)
Trainer, Pressure Gauge (12)
Laboratory Equipment: Beakers, Thermometers, Ice, Table Salt, Bunsen Burners, Stands, Holders (2)
Special Equipment: Goggles, Gloves, Common and Special Tools, Refrigerant Cylinders (1)

Training Methods
Training Film (0.5 hr)
Discussion/Demonstration (7.5)
Performance (7 hrs)
CTT Assignment (5 hrs)
Multiple Instructor Requirements
Safety, Equipment, Supervision (2)

Instructional Guidance
Place adequate emphasis on safety precautions involved in use of bunsen burners, test equipment, and refrigerant transferring procedures.
Outside Assignment: Day 16, direct students to review WBs III-1-P1 and P2; Day 17, P3 and P4; Day 18, P5.

MIR: Two instructors are required for 5 hours during student performance (3 hours in Day 16 and 2 hours in Day 18).

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR

COURSE TITLE: Refrigeration and Air Conditioning Specialist

BLOCK NUMBER: III

BLOCK TITLE: Basic Refrigeration

1 COURSE CONTENT	2 TIME
2. Principles of Refrigeration Condensers, Receivers, Evaporators, and Compressors.	18 (15/3) Day 18 thru 20
a. Using workbook, identify evaporators, receivers, and condensers as to their type, application and required maintenance. STS: 13b(1), 13b(2), 13c, 13d(1), 13d(2), 22a, 22d, 22e. Meas: W	(3/1) Day 18

(1) Purpose and principles of operation of condensers

(2) Factors that affect heat flow from condensers

(3) Types of condensers, their operational features, and methods of capacity control

(a) Air cooled condensers

(b) Water cooled condensers

(c) Evaporative condensers

(4) Purpose of evaporators and their types

(5) Types of evaporators, surfaces, operating conditions, and air circulating features

(a) Types of evaporators

(b) Air circulation

(c) Operating conditions

(6) Types, purposes, and operating principles of receivers

(7) Checking, cleaning, repairing of condensers and evaporators

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COURSE CONTENT

b. Using the pressure enthalpy chart and known pressures, plot an efficiency check of a simple refrigeration cycle to within ±5% of the system capacity. STS: 13a(3), 21g Meas: W, PC (6/2) Day 19

(1) Identify region and scales on chart

(a) Regions

(b) Scales

(2) Identify lines on the pressure enthalpy chart

(a) Saturated liquid line

(b) Saturated vapor line

(c) Constant temperature

(d) Constant enthalpy line

(3) Plotting the basic refrigeration cycle

(a) Given values

(b) Plotting procedures

(4) Data derived from chart

(a) Refrigerant loss

(b) Refrigerant effect

(c) Superheat

(d) Heat of compression

(e) Condensing effects

(5) Given pressures which will apply to a simple refrigeration cycle

COURSE CONTENT

c. Using workbook procedures and tools provided disassemble, inspect, repair, and reassemble a reciprocating compressor to an operative condition. STS: 13a(1)(a), 13a(1)(b), 13a(1)(c), 13a(1)(d), 13a(2), 14g. Meas: W, PC (6/0) Day 20

(1) Centrifugal compressor

(2) Rotary compressor

(3) Reciprocating compressor

(a) Method of operation

(b) Types

(c) Cylinder arrangements

(d) Parts of the reciprocating compressor

(4) Repair of compressors

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-III-2, Condensers, Receivers, Evaporators, and Compressors
WB 3ABR54530-III-2-P1, Location, Identification and Maintenance of Condensers, Receivers, and Evaporators
WB 3ABR54530-III-2-P2, Disassembling a Compressor
WB 3ABR54530-III-2-P3, Reassembly of Compressor
HO 3ABR54530-III-2-H2, Pressure Enthalpy Chart, Its Construction, Use and Value
Pressure Enthalpy Chart, Commercial Diagram

Audio Visual Aids
Charts, Set, Refrigeration System, Refrigeration Compressors, Pressure Enthalpy
Transparencies, Set, Mechanical Refrigeration Components

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

Training Equipment

Trainer, Refrigeration Compressor, Cutaway (12)
Trainer, Simple Refrigeration System (12)
Trainer, Small Walk-in Box (12)
Trainer, Large Walk-in Box (12)
Trainer, 100-Ton Air Conditioning System (12)
Trainer, 25-Ton Air Conditioning System (12)
Trainer, 3-Ton Air Conditioning System (12)
Bench Item, Refrigeration Compressor (1)
Common and Special Tools (1)

Training Methods

Discussion/Demonstration (7 hrs)
Performance (8 hrs)
CTT Assignment (3 hrs)

Instructional Guidance

Place adequate emphasis on safety precautions around operating equipment.
Outside Assignment: Day 18, direct students to review WB III-2-P1; Day 19, P2 and P3.

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER III	BLOCK TITLE Basic Refrigeration

1 COURSE CONTENT	2 TIME
3. Simple Refrigeration System	16 (12/4) Days 21 and 22
a. Using refrigeration trainer and tools provided, fabricate and install lines, pressurize, and leak check a simple refrigeration system observing workbook requirements. STS: 5a, 5b, 5c, 8a, 8b, 8c, 8d, 14b, 14c, 14e, 14h, 14i, 14j, 14l, 14m. Meas: W, PC	(6/2) Day 21
(1) Procedures for installing and removing the manifold gage assembly	
(2) Construction features of a simple refrigeration system	
(3) Charging a system for a leak check	
(4) Using the halide leak detector and soap solution to locate systems leaks	
(5) Procedures for repairing refrigerant leaks	
b. Using refrigeration trainer and tools provided, evacuate and charge a simple refrigeration system to the specification outlined in workbook. STS: 6d(3), 14e, 14h, 14i, 14k, 17e. Meas: W, PC	(6/2) Day 22
(1) Purpose of evacuating	
(2) Service valve and MGA valve positions for evacuating	
(3) Installation, operation, and removal of a vacuum pump	
(4) Service valve and MGA valve positions for charging for normal operation	
(5) Charging methods and procedures for a simple refrigeration system	

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COURSE CONTENT

(6) Interpreting gage reading and performing an operational check of a simple refrigeration system

(7) Pumping down procedures for a simple refrigeration system

(a) Purpose

(b) Service valves and MGA valve positions

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-III-3, Simple Refrigeration System
WB 3ABR54530-III-3-P1, Installing a Manifold Gauge Assembly
WB 3ABR54530-III-3-P2, Assembling a Refrigeration System
WB 3ABR54530-III-3-P3, Charging for a Leak Test
WB 3ABR54530-III-3-P4, Using the Halide Leak Detector
WB 3ABR54530-III-3-P5, Evacuating Procedures
WB 3ABR54530-III-3-P6, Charging a System for Operation
WB 3ABR54530-III-3-P7, Operational Check
WB 3ABR54530-III-3-P8, Pump Down

Audio Visual Aids
Charts, Set, Refrigeration System, Pressure Temperature
Film: TF-5536b, Refrigeration - Evacuating and Charging

Training Equipment
Trainer, Simple Refrigeration System (1)
Bench Item, Vacuum Pump (1)
Special Equipment: Manifold Gauge Assembly, Refrigerant Cylinder, Halide Leak Detector (1)

Training Methods
Discussion/Demonstration (4 hrs)
Training Film (0.5 hr)
Performance (7.5 hrs)
CTT Assignment (4 hrs)

Multiple Instructor Requirement
Safety, Equipment, Supervision (2)

Instructional Guidance
Place emphasis on safety precautions while using refrigeration equipment. Outside Assignments: Day 21, direct students to review WBs III-3-P1 thru P4; Day 22, P5 thru P8.

MIR: Two instructors are required for 3.5 hours in Day 22.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER III	BLOCK TITLE Basic Refrigeration

1 COURSE CONTENT	2 TIME
4. Compressor Checks and Trouble Analysis	22 (16/6) Days 23 thru 25
a. Using refrigeration trainer perform an efficiency check on a reciprocating compressor and record all malfunctions in the workbook. STS: 13a(1)(a), 13a(4), 14h, 14i. Meas: W, PC	(6/2) Day 23
(1) Procedure for oil level check	
(2) Suction valve check procedures	
(3) Discharge valve check procedures	
(4) Operational shaft seal check procedures	
(5) Equalized shaft seal check procedures	
(6) Check compressor for noise, vibration, overheating and abnormal pressures	
b. Using workbook procedures, pressure enthalpy chart and tools provided, perform an efficiency check of the refrigeration system trainer to within ±5% of the system capacity. STS: 14i, 21c(1), 21c(2), 21c(3), 21c(4), 21e, 21f. Meas: W, PC	(10/4) Days 24 and 25
(1) Checking for abnormal low and high side pressure	
(a) Abnormal low side pressure	
(b) Abnormal high side pressure	
(2) Troubles related to condenser fans	
(3) Checking for restrictions, abnormal noises, odors, and security of mounting	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

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    (a) Restrictions
    (b) Abnormal noises
    (c) Odors
    (d) Security of mounting

(4) Plotting low and high side pressures on the P.E. Chart

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-III-4, Compressor Checks and Trouble Analysis
WB 3ABR54530-III-4-P1, Compressor Oil Level Check
WB 3ABR54530-III-4-P2, Compressor Valve Checks
WB 3ABR54530-III-4-P3, Compressor Shaft Seal Checks
WB 3ABR54530-III-4-P4, Using the Trouble Analysis Charts
Pressure Enthalpy Chart, Commercial Diagram

Audio Visual Aids
Charts, Set, Refrigeration System, Pressure Temperature, Pressure Enthalpy

Training Equipment
Trainer, Simple Refrigeration System (1)
Special Equipment: Manifold Gauge Assembly, Halide Leak Detector (1)

Training Methods
Discussion/Demonstration (5.5 hrs)
Performance (10.5 hrs)
CTT Assignment (6 hrs)

Multiple Instructor Requirements
Safety, Equipment, Supervision (2)

Instructional Guidance
Caution students not to tighten oil plug too tight. Use caution when using halide leak detector. Outside Assignment: Day 23, direct students to review WBs III-4-P1 and P2; Day 24, P3; Day 25, P4.

MIR: Two instructors are required for 8.5 hours during student performance (3.5 hours in Day 23, 4 hours in Day 24, and 1 hour in Day 25).

5. Related Training (identified in course chart) 2

6. Measurement Test and Test Critique 2
(2/0)
Day 25

24

STUDY GUIDE 3ABR54530-III-1 thru 4

Department of Civil Engineering Training

Refrigeration and Air Conditioning Specialist

BASIC REFRIGERATION

September 1973

SHEPPARD AIR FORCE BASE

11-7

Designed For ATC Course Use

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17

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BASIC REFRIGERATION

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This supersedes SG 3ABR54530-III-1 thru 4, August 1972

Dept of Civil Engineering Training
Sheppard AFB, Texas

SG 3ABR54530-III-1
17 September 1973

PRINCIPLES OF REFRIGERATION

OBJECTIVE

To help you in learning physics as related to refrigeration, refrigeration cycle, and refrigerants and their characteristics.

INTRODUCTION

It is impossible to say just when and where refrigeration began. Evidence left by prehistoric man indicates that he used ice, snow, and cold water to keep himself and his food supply cool.

The first experiments producing artificial ice began in 1820, but it was not until 1834 that Jacob Perkins, an American engineer, successfully completed a compression type ice-making machine.

There was very little interest in artificial ice making until 1890. That year, a shortage of natural ice and a hot summer emphasized the need for a dependable source of ice.

The first ice-making machines were cumbersome ammonia systems powered by wheels or steam engines.

Household refrigeration began in 1910, but the refrigerators were not very successful as they had to be controlled manually. The first automatic refrigerator was produced in 1918, and the growth of refrigeration has continued at a rapid pace ever since.

The refrigeration industry has made vast improvements in the last 30 years. Each year we see improvements and better utilization of equipment. In the future, we will continue to use refrigeration in the preservation of food and medicine, but the greatest strides in the industry will be in the fields of comfort and equipment cooling.

Automobile air conditioning has made great strides within the last few years. Soon air conditioning will be standard equipment on all new cars.

Equipment cooling in the missile and electronic fields is expanding rapidly. Demands for refrigeration specialists will increase with the development of new equipment.

PHYSICS AS RELATED TO REFRIGERATION

Physics is the study of the natural laws of nature that covers such subjects as mechanics, force, matter, light, sound, pressure, gases, heat, temperature, and the atmosphere. The refrigeration specialist must know the general principles of heat, its measurement and transfer, pressure and its measurement, the gas laws and the atmosphere. A thorough understanding of these subjects is an absolute necessity before the principles of refrigeration can be fully understood.

Matter

Matter is anything that has weight and occupies space. Molecules are the basic structure of all matter and are made up of atoms. Atoms are made up of a nucleus and one or more electrons. The electrons are constantly in motion. The higher the temperature, the faster the speed.

Matter can exist in three states: solid, liquid, and gas. In any of these states, its temperature may be varied. Water at atmospheric pressure exists in the solid state below 32°F, in the liquid state between 32°F and 212°F, and in the gaseous state above 212°F.

It is hard to visualize that there is movement and heat in something as cold and hard as a block of ice. When water is in its solid state (ice) the molecules move much slower than when the same water is in the liquid state. But even if it is ice, the molecules still move because the ice still contains some heat.

The colder the object, the slower the molecules move, and consequently, the less heat the object contains. There is a point known as absolute zero where all molecular action ceases. This is a temperature of approximately - 460°F. Therefore, anything of a temperature above -460°F has some heat.

Heat

Heat is a form of energy. Energy is the ability to do work. A recent development of the use of heat energy is the solar battery. This device receives heat from the sun and converts it to electrical power that can be used to drive motors, etc.

Hot and cold are relative terms. A workman in the steel industry might call a piece of steel too "cold" to work even if its temperature was above 1000°F.

TYPES OF HEAT. Sensible heat is that heat which changes the temperature of a substance. Sensible heat is the intensity of heat within a substance and is measured with a thermometer.

Latent is a word that means "hidden". Therefore, latent heat is hidden heat. It is the heat that causes a change of state without causing a change in temperature.

Latent heat changes a solid to a liquid or a liquid to a solid. It takes 144 BTUs to change one pound of ice at 32°F to water at 32°F. Also, the removal of 144 BTUs from one pound of water at 32°F will leave one pound of ice at 32°F. The heat that causes this change of state cannot be sensed or measured with a thermometer; therefore, it is "hidden heat". Latent heat also changes a liquid to a gas or a gas to a liquid. It takes 970 BTUs to change one pound of water at 212°F to steam at 212°F.

Figure 1 illustrates the changes of state that take place when ice at 0°F is changed to steam at 212°F.

Start at point A with ice at 0°F, add 16 BTUs and the temperature of the ice will increase to 32°F (point B). The specific heat of ice is .5; therefore, one BTU will increase the temperature of one pound of ice 2°F. It requires 144 BTUs to change one pound of ice at 32°F to one pound of water at 32°F. See point C. The addition of 180 BTUs will increase the temperature of the water to 212°F (point D). It requires 970 BTUs (latent heat of vaporization) to change one pound of water at 212°F to steam at 212°F (point E).

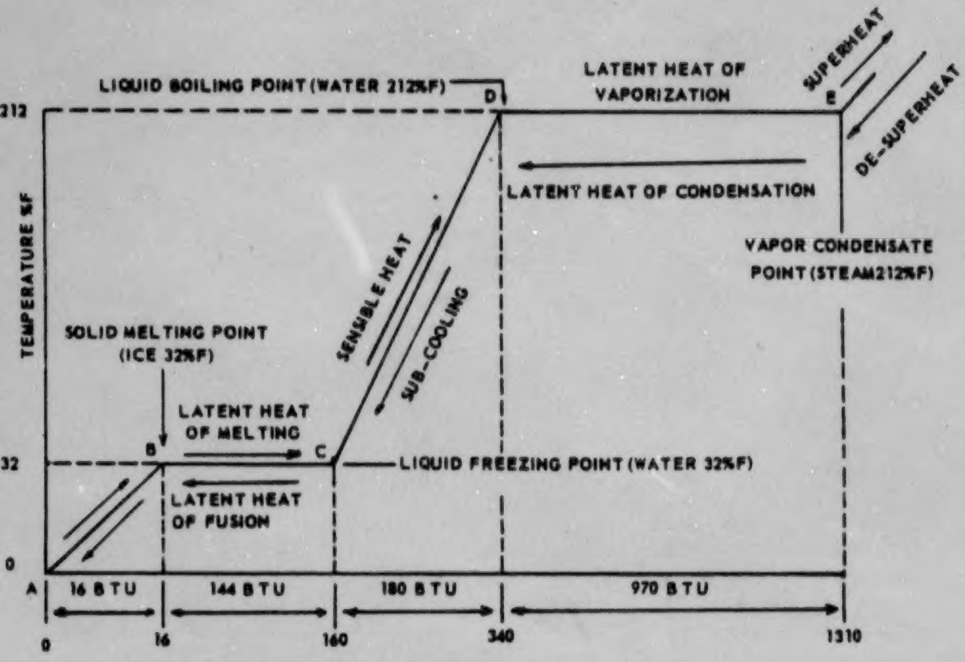

LIQUID BOILING POINT (WATER 212°F)
D
LATENT HEAT OF VAPORIZATION
SUPERHEAT
E
DE-SUPERHEAT
212
TEMPERATURE °F
LATENT HEAT OF CONDENSATION
VAPOR CONDENSATE POINT (STEAM 212°F)
SENSIBLE HEAT
SUB-COOLING
SOLID MELTING POINT (ICE 32°F)
LATENT HEAT OF MELTING
B
C
32
LIQUID FREEZING POINT (WATER 32°F)
LATENT HEAT OF FUSION
0
A
16 BTU
144 BTU
180 BTU
970 BTU
0
16
160
340
1310

Figure 1. One Pound of Water at Atmospheric Pressure

Figure 1 also illustrates the fact that it takes 1310 BTUs of additional heat to change one pound of ice at 0°F to steam at 212°F. All of this heat remains in the steam. To return the one pound of steam back to ice at 0°F would require the removal of 1310 BTUs.

SPECIFIC HEAT. Specific heat is defined as the amount of BTUs required to raise the temperature of one pound of any substance one degree F. Water has a specific heat of 1 because it takes 1 BTU to raise the temperature of one pound of water one degree F. Ice has a specific heat of .5 because one half of a BTU will raise the temperature of one pound of ice one degree F. Figure 2 illustrates the specific heat of several common substances.

NAME	SPECIFIC HEAT
Air	[illegible]24
Oxygen	[illegible]1
Water Vapor	[illegible]
Water	1.0
Ice	.5
Aluminum	.22
Wood	.57

Figure 2. Specific Heat of Common Substances

SUPERHEAT. Superheat is any heat that is added to a gas above its condensing temperature. This additional heat must be removed before a gas can condense to a liquid.

MEASUREMENT OF HEAT. Heat is measured both as to quantity and intensity. The intensity of heat is measured with a thermometer and is expressed in degrees. The quantity of heat cannot be measured; it must be calculated. It is expressed in British Thermal Units (BTU). A BTU IS THE AMOUNT OF HEAT REQUIRED TO RAISE THE TEMPERATURE OF ONE POUND OF WATER ONE DEGREE F. This is approximately the amount of heat produced by burning one common kitchen match. To measure the amount of heat added, it is necessary to know the weight as well as the number of degrees of temperature rise.

THERMOMETERS. A thermometer is an instrument that measures temperature. There are two types of thermometers in general use, the Fahrenheit and the Centigrade. The centigrade scale is used in European countries while the Fahrenheit is more often used in America. Water boils at 212°F and freezes at 32°F measured on the Fahrenheit thermometer scale. Measured on the centigrade thermometer scale, water boils at 100°C and freezes at 0°C.

The temperature range of thermometers varies with their intended use. A thermometer designed for refrigeration service work may range from -40°F to 120°F. A laboratory thermometer may range from 30°F to 600°F. To select a thermometer to measure temperature be sure the range is not exceeded or the thermometer will be destroyed.

Thermometers should be handled carefully at all times. They are usually made of glass and break easily if dropped or placed in a tool box.

HEAT TRANSFER. Heat always flows from a hot to a cold substance until both substances are at the same temperature. Heat is transferred by three methods: conduction, convection, and radiation.

Conduction. Conduction is the transfer of heat by molecular contact. If one end of a copper bar is heated it will not be long until the other end also becomes hot.

Since the molecules in solids are generally closer together than those in a liquid, conduction takes place faster in a solid than in a liquid. Since the molecules in a gas are far apart, conduction through a gas is slow.

Convection. Convection is the transfer of heat by the movement of liquid or gas containing heat. A room is heated by convection; air is first heated and then forced into the room. This air then gives up its heat and raises the temperature of everything in the room.

Natural convection takes place around a space heater. As the air comes close to the heater it is heated, becomes lighter, and rises. As it travels along the ceiling, it gradually becomes cooler and heavier, then settles to the floor to complete the cycle. These convection currents transfer heat throughout the room.

Radiation. Radiation is the transfer of heat by rays, similar in many ways to light rays. When these rays strike our skin they cause the sensation of heat. Heat rays can be felt by holding your hands near a hot stove.

Pressure and Vacuum

Pressure is force per unit area. A pressure of 30 p.s.i. means that there is a force of 30 pounds being exerted on each square inch of surface area. The air above us has weight; therefore, at sea level air exerts a force of 14.7 pounds on each square inch of the earth's surface. When climbing a mountain, the force of the air decreases because the column of air is shorter than it is at sea level. (See figure 3.)

A vacuum is any pressure below atmospheric pressure. A perfect vacuum would be completely free of all gases; an absolute empty space.

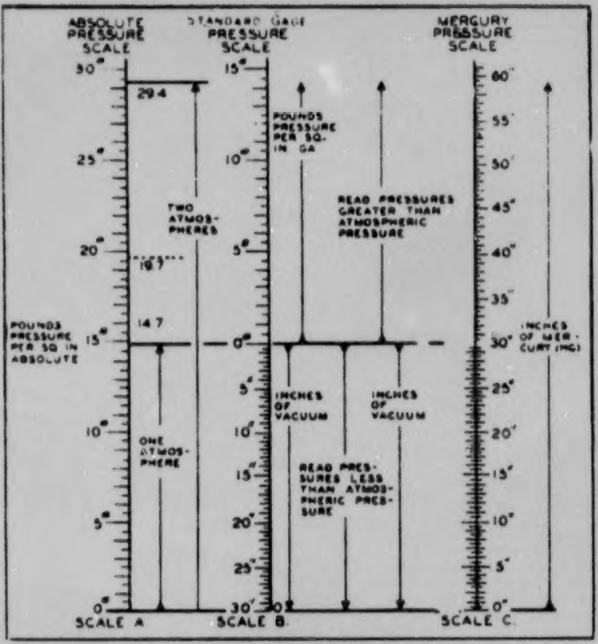

ABSOLUTE PRESSURE SCALE
STANDARD GAGE PRESSURE SCALE
MERCURY PRESSURE SCALE
30"
29.4
25"
TWO ATMOS-PHERES
20"
19.7
14.7
POUNDS PRESSURE PER SQ IN ABSOLUTE
15"
10"
ONE ATMOS-PHERE
5"
0"
SCALE A
15"
POUNDS PRESSURE PER SQ. IN GA
10"
5"
0"
READ PRESSURES GREATER THAN ATMOSPHERIC PRESSURE
5"
INCHES OF VACUUM
INCHES OF VACUUM
10"
15"
READ PRES-SURES LESS THAN ATMOS-PHERIC PRES-SURE
20"
25"
30"
SCALE B
60"
55"
50"
45"
40"
35"
30"
INCHES OF MER-CURY (HG)
25"
20"
15"
10"
5"
0"
SCALE C

Figure 3. Pressure Scales

The operation of a mechanical refrigeration system depend directly on a difference in pressure. The pressure is high in one part of the system and low in another part.

PRESSURE AND VACUUM MEASUREMENT. Pressure and vacuum is measured in a number of ways, the difference being mostly for convenience. Since these differences exist, it is necessary to specify exactly which measurement is being used.

Absolute Scale. The absolute scale is based on the total pressure exerted by the atmosphere at sea level. Therefore, an absolute scale will indicate a press of 14.7 p.s.i.a. at sea level. A perfect vacuum would be indicated as 0 p.s.i.a. (See figure 3.)

Standard (Gage) Scale. The standard scale is based on the difference between atmospheric pressure and added pressure. A standard scale will indicate 0 p.s.i.g. at sea level. An example, if the pressure in a tire is indicated to be 30 p.s.i.g., it means that the pressure is 30 p.s.i. more than atmospheric pressure.

Compound (Gage) Scale. The compound is used to measure pressures above and below atmospheric. Pressures below are indicated as so many inches of mercury vacuum. Pressures above atmospheric are indicated as p.s.i.g.

Mercury Scale. The mercury scale is based on the same principles as the absolute scale. However, the pressure is indicated in inches of mercury rather than pounds per square inch.

EFFECTS OF PRESSURE AND VACUUM. The basic refrigeration cycle depends on the effects of pressure upon its circulating refrigerant. By controlling the pressure on a liquid, the temperature at which it will boil can be predetermined. Water boils at a temperature of 212°F, but by controlling the pressure, the boiling point can be varied from 32°F up to around 700°F.

The boiling point of a liquid and the condensing point of its gas is the same temperature at any given pressure. If the pressure is increased, the boiling and condensing points increase. If the pressure is decreased, the boiling and condensing points decrease.

A vacuum lowers the boiling and condensing point lower than that which normally occurs at atmospheric pressure.

Saturation Temperature

Saturation temperature is the boiling or vaporizing temperature of a liquid at any given pressure and the condensing temperature of a gas or vapor at any given pressure.

Gas Laws

There are several different laws of gases derived by several different physicists and scientists. However, the refrigeration and air conditioning specialist is only interested in three of these laws. Since all of the principles of refrigeration are based on these laws, a complete understanding of them is essential.

BOYLE'S LAW. Boyle's law states that "the volume of gas varies inversely as the pressure providing the temperature remains constant." If a given volume of gas (two cubic feet) at a given pressure (30 p.s.i.) is compressed to one cubic foot, the pressure will increase to 60 p.s.i., providing the temperature remains constant. In reality, the temperature will not remain constant but will increase.

CHARLES' LAW. Charles' law states that "a volume of gas varies directly with the temperature providing the pressure remains constant." If the temperature of a given volume of gas (two cubic feet) at a given temperature (50°F) and a given pressure (60 p.s.i.) is increased to 100°F, the volume will increase to four cubic feet, providing the pressure remains constant.

The principles of refrigeration are based on a combination of these two laws. If the volume of a gas is decreased both the temperature and pressure will increase.

DALTON'S LAW. Dalton's law states that "the total pressure of a mixture of gases is the sum of the partial pressures of each of the gases in the mixture."

In a cylinder containing a mixture of R-12, ammonia, and air; each of these gases exerts a given pressure. If the R-12 has a pressure of 20 p.s.i.g., the ammonia 40 p.s.i.g., and the air 100 p.s.i.g., the total pressure as indicated by a standard pressure gage would be 160 p.s.i.g.

REFRIGERATION

Refrigeration is the transfer of heat from a place where it is not wanted to a place where it is unobjectionable.

Compression Refrigeration Cycle

Starting at the liquid receiver (figure 4) the refrigerant is under high pressure and in a liquid state. This liquid goes up the liquid line and through the refrigerant control into the evaporator. The liquid in a low pressure area will absorb heat and turn into a gas. If the liquid is R-12 and the pressure in the evaporator is 37 p.s.i.g., the refrigerant will turn to a gas at 40°F, its heat will flow into the liquid until its temperature is reduced to 40°F.

The heat laden gas in the evaporator is drawn down the suction line into the suction side of the compressor. This gas is full of heat absorbed in the evaporator. The compressor compresses this heat laden low pressure gas to a high pressure gas and discharges it to the condenser.

The high pressure gas is hot, possible over 100°F. If cooler air is passed over the condenser, the heat in the hot gas will flow into the air. As the hot gas loses its heat it turns to a liquid. The liquid now runs into the receiver. The liquid has completed one cycle. It has picked up heat in an area where it was not wanted and has discharged it into another area where it is not objectionable.

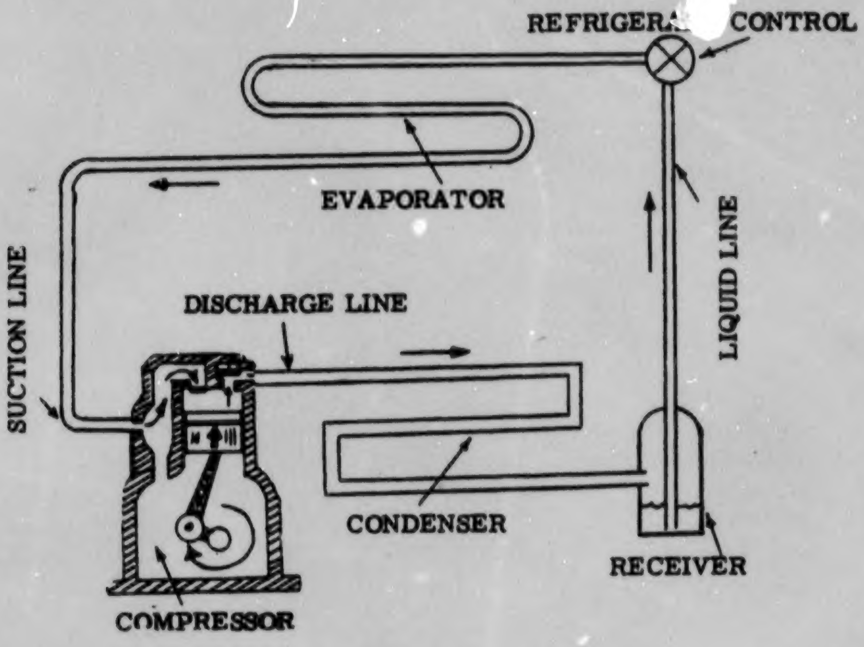


Figure 4. Compression Refrigeration Cycle

Units necessary for the operation of a basic refrigeration system are the compressor, condenser, evaporator, refrigerant control, and interconnecting lines.

COMPRESSOR. The compressor is used to compress the heat laden low pressure gas and discharge it to the condenser as hot high pressure gas. The compressor is located between the evaporator and the condenser.

CONDENSER. The condenser removes the heat from the gas and changes the gas into a liquid. The condenser is located between the compressor and the refrigerant control.

REFRIGERANT CONTROL. The refrigerant control changes the high pressure liquid into a low pressure, low temperature liquid. It must be adjusted to meter the liquid refrigerant into the evaporator as fast as the compressor removes it. The refrigerant control is located between the condenser and the evaporator.

EVAPORATOR. The evaporator absorbs heat from the refrigerated space and changes the low pressure liquid into a gas. It is located between the refrigerant control and the compressor.

RECEIVER. The receiver is a metal cylinder that acts as a storage space for the surplus refrigerant in a system. Most small systems do not have receivers. The receiver when used, is located between the condenser and the refrigerant control.

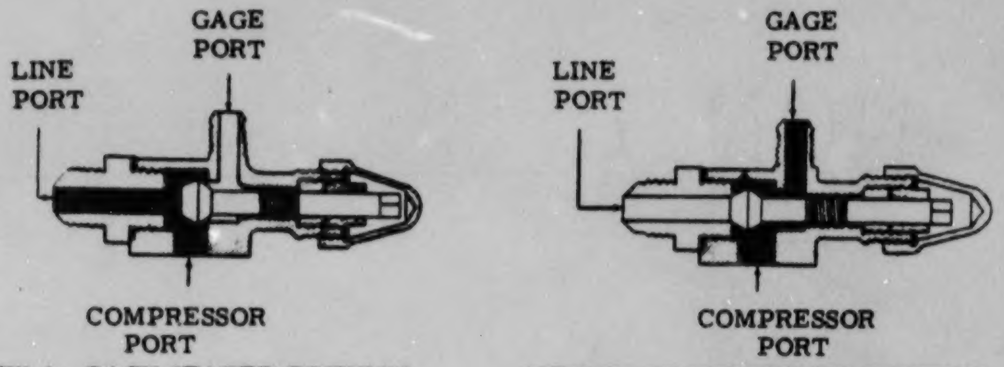
Valves and Gages

Valves and gages are the refrigeration and air conditioning specialists' most important tools. Valves are used to isolate various parts of the system and gages are used to indicate what is happening within the system.

SERVICE VALVES. Service valves are used to facilitate the installation and removal of the manifold gage assembly and to isolate the refrigerant lines from the compressor. They are located at the suction and discharge ports of the compressor.

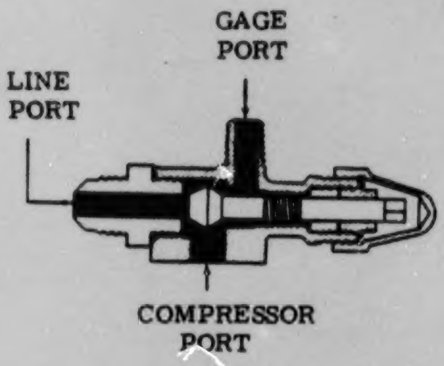
Service valves have three positions. (See figure 5.)

View A illustrates the back seated position. In this position the compressor is open to the refrigerant line, but the gage port is closed. View B illustrates the front seated position. The compressor is open to the gage port, but the line port is closed. View C illustrates the gage position. All ports are open. This is the normal operating position.


LINE PORT
GAGE PORT
COMPRESSOR PORT
LINE PORT
GAGE PORT
COMPRESSOR PORT

VIEW A: BACK SEATED POSITION

VIEW B: FRONT SEATED POSITION


LINE PORT
GAGE PORT
COMPRESSOR PORT

VIEW C: GAGED POSITION

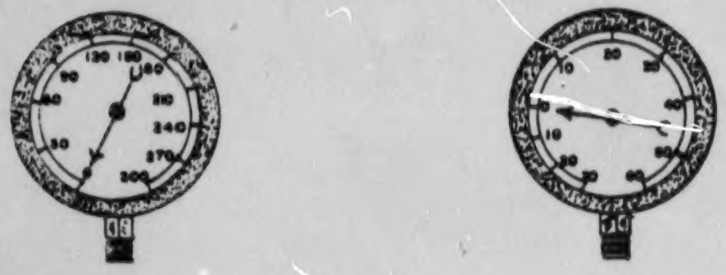
Figure 5. Compressor Service Valves

RECEIVER (KING) VALVE. The receiver valve, located at the outlet of the receiver is used to close the line so as to isolate the liquid line, evaporator, and suction line from the rest of the system. The receiver valve is often called the "king" valve.

GAGES. There are two types of gages used to record pressures within the refrigeration system. They are the high pressure gage and the compound gage. (See figure 6.)

High Pressure Gage. The high pressure gage is installed to the compressor discharge line to indicate the pressure in the high side of the system.

Compound Gage. The coupound gage is installed to the compressor suction line to indicate the pressure in the low side of the system. The compound gage will indicate either pressure or vacuum.


120
150
180
90
210
60
240
30
270
300
10
20
30
0
40
10
50
20
30
60

High Pressure Gage

Compound Gage

Figure 6. Gages

Manifold Gage Assembly

The manifold gage assembly is designed to facilitate the installation and removal of the gages and to aid in various service procedures. The manifold gage assembly (figure 7) contains one high pressure gage, one compound gage, two valves, and three ports.

The manifold gage assembly can be used to purge the system, evacuate the system, charge the system, check system pressures, by-pass pressures, and add oil to some systems.

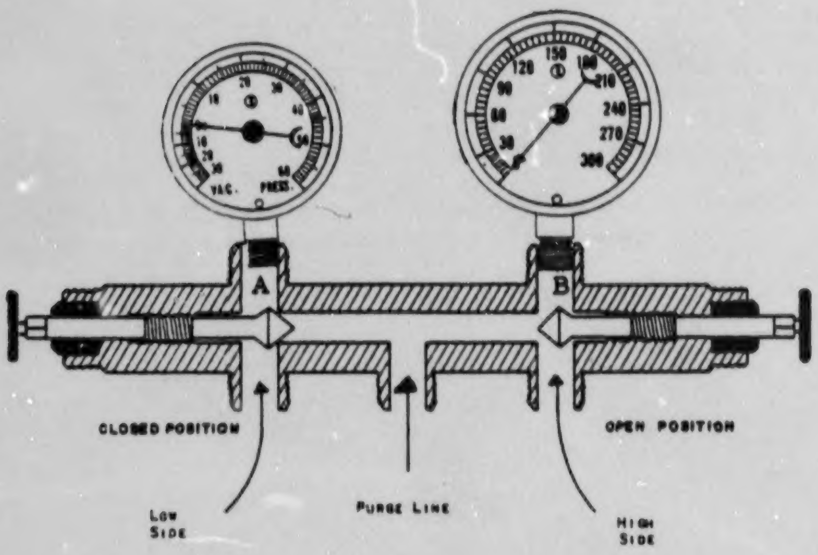

10
20
30
40
50
60
VAC.
PRESS.
120
150
180
90
210
60
240
30
270
300
A
B
CLOSED POSITION
OPEN POSITION
LOW SIDE
PURGE LINE
HIGH SIDE

Figure 7. Manifold Gage Assembly

Temperature - Pressure Charts

The temperature - pressure chart is a ready means of converting refrigerant pressures to saturation temperatures. It can only be used when the refrigerant exists as both a liquid and gas in the same side of the system. The charts are a quick means to check out a system for operation and trouble analysis. They have been reduced in size to small cards for convenient use outside the refrigeration shop.

The charts and cards consist of vertical columns. One column lists saturation temperature in degrees Fahrenheit and the other columns contain the equivalent pressure relationship for each refrigerant named thereon.

The temperature - pressure chart is a very important tool. Learn to use it and refer to it often.

REFRIGERANTS

In the development of refrigeration, several different chemicals and fluids have been used as refrigerants. The most successful refrigerants are the halocarbons.

No refrigerant is completely satisfactory in all applications. A refrigerant may work very well in air conditioning systems, but be worthless for use in cold storage plants.

Desirable Refrigerant Characteristics

The refrigerant that has the most of these characteristics is normally the best.

1. It should be nonpoisonous.
2. It should be nonexplosive.
3. It should be noncorrosive.
4. It must be nonflammable.
5. Leaking refrigerant should be easily located.
6. It should operate under low pressure.
7. It should be a stable gas.
8. It must not destroy the lubricating properties of the oil.
9. It should be nontoxic.
10. It should have a high latent heat of vaporization per pound.
11. The refrigerant gas must have a small relative displacement per pound of liquid refrigerant.

Common Refrigerants

HALOCARBON COMPOUNDS. Chemists experimenting with methane and ethane found that by substituting chlorine or fluorine for the hydrogen they could make almost any type refrigerant needed. The refrigerants thus formed are known as halocarbons. All of these refrigerants are:

1. Nonflammable
2. Nonexplosive
3. Nonirritating
4. Nontoxic
5. Odorless
6. Very stable chemically
7. Noncorrosive
8. Harmless to refrigerated products

These refrigerants are available under such trade names as Freon, Genetron, Isotron, Ucon, and several others. To eliminate the use of the long cumbersome chemical names each refrigerant has been assigned a number. (See table 1.)

REFRIGERANTS

NAME	CHEMICAL FORMULA	ASRE NUMBER	LATENT HEAT	BOILING POINT
TRICHLOROMONOFLUOROMETHANE	CCL_3F	R-11	93 BTU	74° F
DICHLORODIFLUOROMETHANE	CCL_2F_2	R-12	69 BTU	-21° F
MONOCHLORODIFLUOROMETNANE	$CHCLF_2$	R-22	93 BTU	-41° F
MONOCHLOROTRIFLUOROMETHANE	$CCLF_3$	R-13	45 BTU	-114° F
AZEOTROPES	$CCL_2F_2/$ CH_3CHF_2	R-500	82.5 BTU	-28° F

Table 1

Halocarbon refrigerants act as a solvent on natural rubber so all gaskets and seals must be made of synthetic rubber.

Trichloromonofluoromethane (R-11). This refrigerant was designed for use in centrifugal type compressors. Each pound of the liquid makes 5.77 cubic feet of gas, but the difference between the low and high sides is small. This means that we must handle a large volume of gas, but the compression ratio is very small.

With a 40 degree evaporator temperature, the low side pressure is 15 inches vacuum and the condensing pressure at 80 degrees F is about 5 p.s.i.g. This makes a total of only 12 to 13 p.s.i. between the low and high side.

Lubrication is not a problem with R-11. Any good dehydrated high temperature oil will work very satisfactorily.

Leak testing becomes a problem especially with very small leaks. The pressure is only 5 p.s.i.g. at 80°F so a small leak may be very hard to find. To find a small leak it may be necessary to evacuate the complete system and then charge it with CO_2.

Dichlorodifluoromethane (R-12). This is the most widely used of the halocarbon refrigerants. It is used extensively in air conditioning, domestic, commercial, and industrial installations. Its boiling point is 21 degrees below zero at atmospheric pressure, and its condensing pressure is 100 to 130 p.s.i.g. at room temperature. It will only move 69 BTUs of heat for each pound of liquid. This is a decided advantage in smaller refrigerating machines. The large amount of liquid circulated allows the use of larger, more accurate refrigerant and motor controls.

Like all halocarbon refrigerants, R-12 is miscible with oil. On a correctly installed system, operating above zero degrees F, there are very little oil return problems. Any good, dehydrated, nonfoaming, refrigeration oil can be used.

Leaks are very easily detected provided there is at least 60 p.s.i. refrigerant pressure in the system.

Monochlorodifluoromethane (R-22). This refrigerant was developed for use in home cold storage units. Its boiling temperature of -41° F allows an evaporator temperature of -40° without going into a vacuum on the low side. Its latent heat of 93 BTUs is somewhat higher than R-12. This allows the use of a smaller compressor and lines. However, the higher condensing pressure (200 p.s.i.) requires the same amount of power per ton of refrigeration.

Window air conditioning units use R-22 as a refrigerant. The main advantage is smaller size and less manufacturing cost. The operating cost of R-12 and R-22 systems is approximately the same.

In systems with an evaporator temperature of less than zero degrees F, the oil will float on top of the refrigerant. Some method must be provided for this oil to return to the compressor. An oil separator will help, but it does not eliminate the problem. R-22 will dewax the oil, so a highly dewaxed oil must be used.

Leak detection for R-22 is the same as for R-12.

Monochlorotrifluoromethane (R-13). This refrigerant was developed for use in ultra-low temperatures. Its boiling temperature is -114°F at atmospheric pressure. This will allow an evaporator temperature of 110 degrees below zero and still maintain a positive pressure in the low side. However, due to its extremely high condensing pressure, this refrigerant is unsuitable for use in normal refrigeration units.

Azeotropes. Is a mixture of two or more refrigerants which, in combination, acts as one compound (R-500, R-502, R-503).

REFRIGERANT CYLINDERS. With the exception of R-11, all refrigerants are transported in special refrigerant cylinders. These cylinders come in three main sizes: 145 pound, 25 pound, and 10 pound. The 145 pound size is used for storage and shop purposes, while the others are used for servicing work. To calculate the amount of weight for each size cylinder, three weights are necessary.

Refrigerant	- net	145	25	10
Cylinder	- tare	60	17	7
Total	- gross	205	42	17

Refrigerant cylinders are usually equipped with fusible plugs. These plugs are designed to blow out under high pressure to prevent the cylinder from exploding.

TRANSFER OF REFRIGERANTS. Refrigerant is obtainable in amounts from a railroad carload to a small one pound or less can. However, most refrigerants come in cylinders containing 145 pounds. The refrigerant is then transferred into smaller cylinders for ease of handling.

A simple method for transferring refrigerants from large to small cylinders is shown in figure 8. This is a simple stand on which the large refrigerant cylinder is mounted in an inverted position. This stand must be so constructed that the cylinder valve is easily accessible. One-fourth inch charging line should run from the storage cylinder to the service cylinder. The refrigerant will flow into the small cylinder comparatively slow. Refrigerant will always flow to the coldest point in a system; therefore, if we cool the small cylinder, the refrigerant will flow into it much faster.

NOTE: Cooling the smaller cylinder will lower the pressure allowing the refrigerant to flow into it.

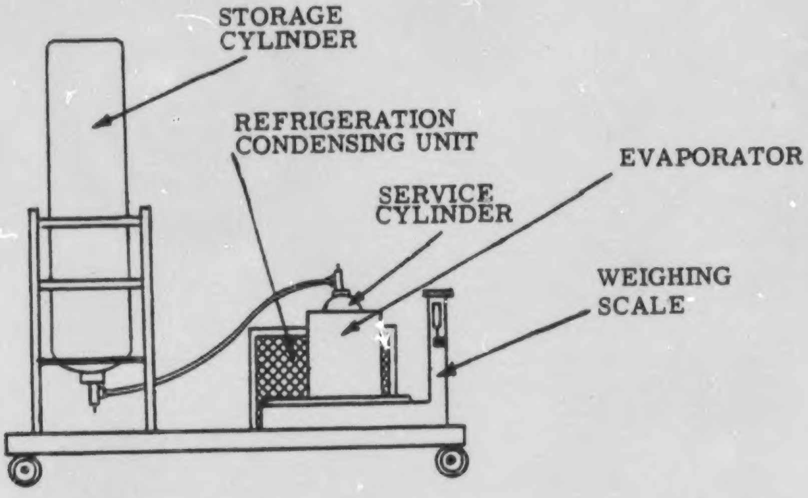


Figure 8. Transferring Refrigerant

The exact amount of refrigerant transferred may be determined by placing the service cylinder on a weighing scale during the transfer procedure.

CAUTION: Never fill a refrigerant cylinder more than 85 percent full!

REFRIGERANT SAFETY

OBJECTIVE

To help you learn the hazards present in accomplishing your duties and the prescribed safety procedures to observe to avoid personnel injury or equipment damage.

INTRODUCTION

One drop of a low temperature refrigerant on the eye ball will freeze the eye and cause blindness. For that reason, the use of goggles when handling liquid refrigerant cannot be over emphasized.

FIRST AID

Injury from Refrigerant is Divided into Three Classes.

LIQUID ON THE SKIN. When liquid refrigerant comes in contact with the skin, it vaporizes so fast that it freezes the skin. The affected area will break out in water blisters that look like burns. If medical aid is available within a few minutes, do not attempt to medicate. Flush the area with water. If medical aid is not available, treat the wound the same as a burn.

LIQUID OR VAPOR IN THE EYES. Avoid rubbing the eyes, flush with water, introduce a few drops of sterile mineral oil and wash with a weak solution of boric acid. Seek medical aid. There is not much that can be done after liquid refrigerant is in the eyes. The best first aid is to use extreme care and wear goggles.

VAPOR OR GAS INHALATION. The first thing to do is remove the overcome person from the contaminated area. If there are two or more persons available, make sure only one enters the area at a time. Wear goggles and hold your breath. If you cannot remove the person without breathing, return to the outside, get your lungs full of fresh air and then enter the contaminated area again. Do not breathe in the contaminated area or you will be overcome also. As soon as the overcome person is out in the fresh air, remove any contaminated clothing, give artificial respiration and seek medical aid.

HANDLING REFRIGERANT CYLINDERS

During the construction of a large building, one of the construction men turned over a refrigerant cylinder and sat on it to eat his lunch. After the lunch period, he got up and went back to work. The cylinder rolled over next to a hot stove. The fusible plug failed to blow and the cylinder exploded. It blew out all the windows and damaged the building extensively.

Refrigerants are not dangerous if handled with a little care, but under certain conditions, they can do as much damage as dynamite.

The following rules must be followed when handling refrigerant cylinders:

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1. Never drop cylinders. Refrigerant cylinders are built very sturdily to hold the required pressures; however, they should be handled with care.

2. Tie cylinders securely when transporting. DO NOT just throw the cylinders in a truck and take off. You may hit a bump or have to stop very suddenly. This could throw the cylinders around, causing them to explode.

3. Close all valves tightly.

4. Make sure protective caps are in place when not in use. Regardless of how careful we are, a cylinder might be knocked over. The weakest point on the cylinder is the valve. If this valve is broken off, the cylinder will be projected across the floor with enough force to break a man's leg.

5. Never mix refrigerants in cylinders. Refrigeration shops usually keep cylinders of all types of refrigerants. Make sure these cylinders are well marked so there can be no mistake in getting two types of refrigerants mixed.

6. Never put anything but refrigerant in refrigerant cylinders. Under no circumstances should you put anything but the correct refrigerant in a refrigerant cylinder. Carbon dioxide, nitrogen, and compressed air are necessary in a refrigeration shop, but they must be kept in their own containers.

7. Never use cylinders for rollers or supports. This comes under the heading of misuse of equipment. Most accidents in a shop are the result of the misuse of equipment. If you use your equipment correctly, you will not get hurt and the equipment will last longer and work better.

8. Never tamper with safety devices. These devices are designed to save your life! They may not function correctly if they have been tampered with.

9. Never attempt to repair a cylinder. If a cylinder leaks or is damaged in any manner, turn it in to be salvaged. Trying to repair a cylinder is an invitation to disaster.

10. Never permit a flame to come in contact with a cylinder. The pressure of a refrigerant is the result of its temperature. The higher the temperature the higher the pressure. If we raise the temperature of the refrigerant enough, the pressure will increase until something has to give. Every year there are several accidents as the result of heating refrigerant cylinders with a flame.

11. Never fill a cylinder more than 85 percent full. All liquids expand as their temperature increases. If a cylinder is completely full of liquid and the temperature increases, the pressure will be great enough to burst the cylinder.

12. Do not place cylinders where they might become part of an electrical circuit.

13. Do not deface or remove any markings on cylinders. If you find a cylinder improperly labeled, notify the Safety Officer.

14. Do not store full cylinders with empty cylinders.

15. Protect cylinders from direct sun rays.

HANDLING REFRIGERANTS

In the presence of an open flame or hot surface, halocarbon refrigerant decomposes into phosgene gas. Although dangerous, this gas gives sufficient warning of its presence so that the serviceman can ventilate the area.

Some refrigerants are classified as nonpoisonous, but breathing large quantities will damage the lungs. In smaller concentrations, they act as a mild anesthetic, resulting in dizziness and drowsiness.

When transferring refrigerant from one cylinder to another, liquid refrigerant is being handled. Be safe, wear goggles and rubber gloves.

SUMMARY

Refrigeration, the transfer of heat from a place where it is not wanted, is almost as old as history. The growth of mechanical refrigeration in the past few years has been greater than all the previous years combined.

Heat is a form of energy. It affects all substances around us, causing them to be in one of three physical states, depending on temperature: solid, liquid or gas. Heat in the summertime, is uncomfortable where people gather. Heat causes food to spoil and medicine to deteriorate.

Heat flows from hot to cold by three methods: conduction, convection and radiation. Its intensity is measured in degrees of temperature, while its quantity is measured in BTUs.

A refrigeration system depends directly on a difference in pressure for its basic principle of operation. Pressure affects the boiling point of a liquid refrigerant and the condensing point of a gas.

A compression refrigeration system has four major component parts: compressor, condenser, refrigerant control, and evaporator. The fluid circulated inside the system is called the refrigerant. It is this fluid that carries the heat in the refrigeration cycle.

The service valves, gages, and manifold gage assembly are designed to allow servicing and checking the refrigeration system.

Refrigerants are available in various sized containers, from a small can to a large cylinder. Refrigerant is transferred from large storage cylinders into smaller service cylinders for ease in handling and economy.

The overall goal of the ground safety program is to prevent accidents. A large percent of all accidents can be prevented if prescribed rules and precautions are strictly followed. Some of the conditions that cause accidents are horseplay, poor housekeeping practices, disregard of warning signs, improper selection and use of tools, laziness, and just plain carelessness. Take the necessary time to learn and observe the pertinent rules for each job assignment. Remember, an ounce of prevention is worth much more than a pound of cure. Be safety-minded!

QUESTIONS

1. What is sensible heat?
2. What is the difference between quantity and intensity of heat?
3. Name the three methods of heat transfer.
4. What is latent heat?
5. What is the definition of convection?
6. Define superheat.
7. How can the boiling point of a liquid be decreased?
8. Define heat.
9. How many Btus of latent heat is required to change one pound of ice at 32°F to water at 32°F.
10. How many Btus will it take to change one pound of ice at 0°F to water at 50°F.
11. What is specific heat?
12. What is the specific heat of one pound of ice?
13. What is the specific heat of one pound of water?
14. How many Btus of sensible heat is required to change one pound of ice at 10°F to water at 42°F?
15. Define pressure.
16. What is the definition of refrigeration?
17. Name the four major components of a refrigeration system.
18. Name the three positions of a compressor service valve.
19. Name two types of gages used to record the refrigeration system pressure.
20. What is another name for the receiver outlet valve?
21. What position should the compressor service valves be in for normal operation?
22. Name two desirable characteristics for refrigerant.
23. How full should a refrigerant cylinder be filled?
24. What are three classes of refrigerant injuries?
25. What is done when a cylinder is damaged and in need of repair?

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CONDENSERS, RECEIVERS, EVAPORATORS, AND COMPRESSORS

SECTION I

CONDENSERS, RECEIVERS AND EVAPORATORS

OBJECTIVE

To help you in learning types, purpose and principles of operation of condensers, receivers and evaporators.

INTRODUCTION

Since there are many types of condensers, receivers and evaporators in current use, it is important to know something of the design and operation of each of these units. Also, it is important to know the application of these devices in a refrigeration system.

CONDENSERS

The condenser is one of the major parts of a refrigeration system. The heat that is picked up in the evaporator is disposed of by the condenser. The condenser changes the high pressure and high temperature gas to a high pressure liquid.

The compressed heat laden gas must give up its heat before it can return to the liquid state. This giving up of heat is accomplished in the condenser. The rate of heat transfer depends upon the following factors:

1. Surface area
2. Type of cooling medium (Air, Water)
3. Temperature of the cooling medium
4. Material
5. Condition of the surface
6. Amount of cooling medium

The following three things take place in a condenser:

1. Desuperheating
2. Condensing
3. Subcooling

Desuperheating

Before any condensation can take place, the highly superheated gas must have the superheat removed from it. This is called "desuperheating" and occurs in the discharge line and in the first few coils on the condenser.

Condensing

After the superheat is removed, the gas is at its saturation temperature. At this point the gas gives up its latent heat and returns to a liquid.

Subcooling

After the gas has condensed to liquid, its temperature is still above that of the cooling medium. In the last coils of the condenser, the liquid gives up sensible heat to the cooling medium. This is known as subcooling.

You can prove the existence of these three functions by running your hand over a condenser that has been operating for an hour or so. The top coils will be much warmer than the middle coils. The middle coils will be warmer than the lower coils.

There are three main types of condensers:

1. Air cooled.

2. Water cooled.

3. Evaporative

AIR COOLED CONDENSERS. An air cooled condenser uses ambient air as the cooling medium. The two types of air cooled condensers are natural and forced convection. Condensers are normally made of steel or copper tubing, with or without fins.

Some domestic refrigerators utilize natural circulation of air. These are equipped with condensers which consist of tubing mounted on the back of the refrigerator. By allowing a space between the box and condenser, air flows similar to that in a chimney and no fan is necessary.

Maintenance for air cooled condensers is much less than that required for other types of condensers. For this reason, refrigeration systems of 100 tons are being built with air cooled condensers for use in cooler climates.

Some disadvantages of using air cooled condensers in systems above three tons are:

1. Higher head pressure results in greater operating cost and reduced unit efficiency.

2. Power to drive the condenser fan is sometimes excessive.

3. Condenser fan noise may become objectionable.

All air cooled condensers must have adequate ventilation for the best results.

WATER COOLED CONDENSERS. The water cooled condenser uses water as the cooling medium. The capacity is controlled by regulating the amount of water through the condenser. Water cooled condensers have the following advantages over air cooled types:

1. More compact.

2. Higher heat transfer.

3. Lower head pressure.
4. Increased condensing unit capacity.

The main disadvantages are:

1. High water cost.
2. Cooling tower maintenance.
3. Cost of installation.

Water cooled condensers are classified into three general groups:

1. Shell and coil.
2. Double tube.
3. Shell and tube.

SHELL AND COIL CONDENSER. The shell and coil condenser consists of a welded shell containing a finned water coil. The refrigerant is between the shell and coil and the water is inside the coil. The water must be reasonably clean and free from minerals since the coil must be cleaned by chemicals circulated in the water. (See figure 9 .)

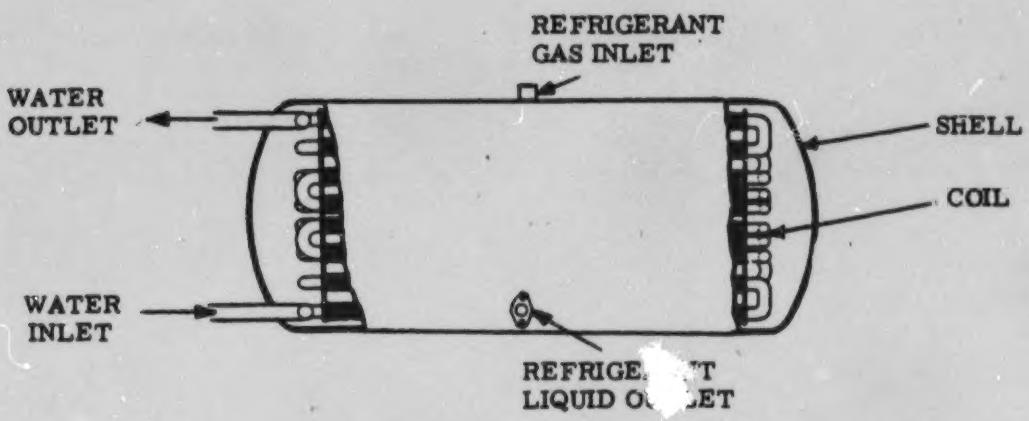
REFRIGERANT GAS INLET
WATER OUTLET
SHELL
COIL
WATER INLET
REFRIGE[illegible]T LIQUID OU[illegible]ET

Figure 9. Shell and Coil Water Cooled Condenser

DOUBLE TUBE CONDENSER. The double tube condenser is a tube within a tube. (See figure 10) The refrigerant is between the inner and outer tube. The water flows in the opposite direction in the inner tube. This counterflow action gives high efficiency. The water used must be clean and free of minerals as the internal cleaning of the condenser must be by chemicals circulated in the water.

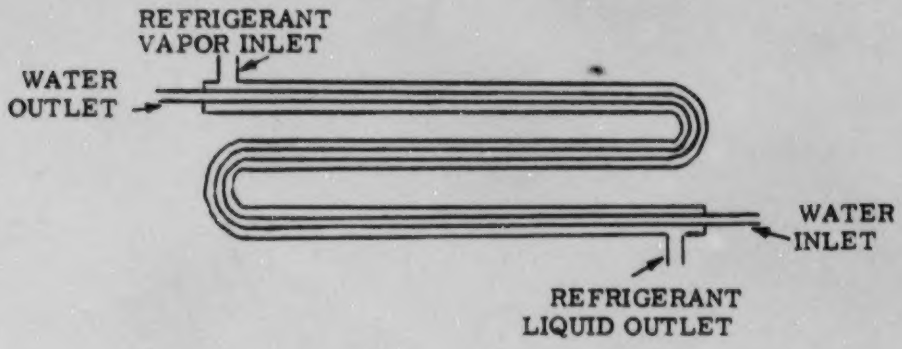

Figure 10. Double Tube Water Cooled Condenser

SHELL AND TUBE CONDENSERS. Shell and tube condensers are made of a steel shell with tube sheets at each end. Copper tubing runs from one of these sheets to the other. Iron heads bolt on each end of the condenser. Water flows into one of these heads and out the other. The refrigerant is between the steel shell and the copper tubing. From a maintenance standpoint, this is the best type of water cooled condenser. The heads may be removed and the tubes cleaned out mechanically with a revolving brush. The shell also serves a receiver.

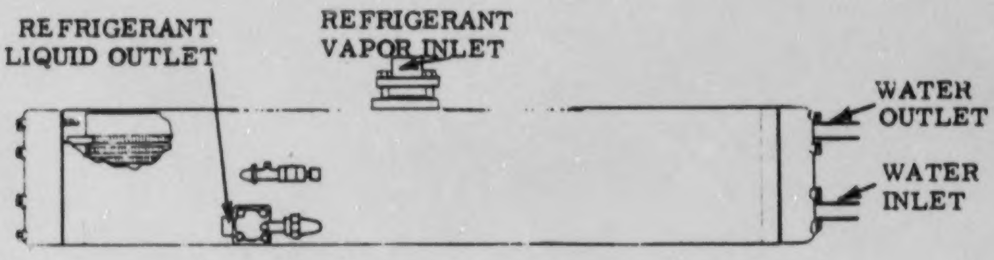

Figure 11. Shell and Tube Water Cooled Condenser

EVAPORATIVE CONDENSER. The evaporative condenser is cooled by water sprayed directly over the condensing coils. The evaporated water carries away the heat of condensation. The remaining water drops to a sump under the condenser where it is recirculated by a pump. A fan draws air over the condenser coils to increase the cooling capacity. Each pound of water evaporating on the condenser removes 970 BTUs of heat from the refrigeration system. (See figure 12.) The evaporative condenser is designed to be used where the temperature varies from very hot to very cold in a year's time.

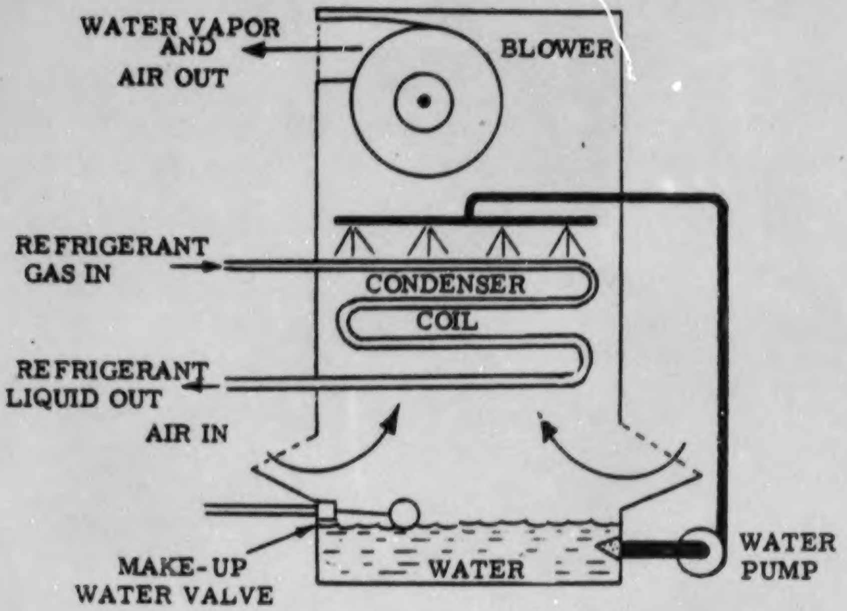

Figure 12. Evaporative Condenser

RECEIVERS

The receiver is a storage tank for the surplus refrigerant in the system. Without a receiver in the system, the amount of refrigerant charge would have to be critical.

The receiver is normally large enough to hold the complete refrigerant charge. This allows work on the low side without removing the refrigerant from the system. The two types of receivers are the vertical and horizontal. The inlet is normally at the top and the outlet at the bottom. When the outlet is at the top, an internal pipe or dip tube extends to the bottom. This is to insure that a liquid seal is maintained at the outlet to prevent vapor from entering the liquid line.

When installing a receiver, be sure that the internal pipe or dip tube is installed in the outlet port.

Small refrigeration units do not have any method of determining the liquid level in the receiver. Sight glasses are sometimes used, but are not satisfactory due to the danger of breakage.

The receiver should be about 1/3 to 1/4 full of liquid refrigerant when the system is operating. This will leave room for the surplus refrigerant when the system is pumped down.

A large system using a shell and tube water cooled condenser does not need a separate receiver. The bottom one-third of the condenser is utilized as a receiver.

This application is referred to as a condenser-receiver. Care must be taken to prevent over-charging the system. If any of the water coils are covered with liquid refrigerant the head pressure will increase reducing the compressor efficiency.

EVAPORATORS

The evaporator absorbs heat from the refrigerated space and changes the low pressure refrigerant liquid into a gas. It is often referred to by such names as boiler, freezing unit, coil, and low side. The temperature of the evaporator must be lower than that of the refrigerated space. This will allow the heat in the refrigerated space to flow into the evaporator. There are two basic types of evaporators, dry and flooded.

Classification of Evaporators

Evaporators are classified under four groups according to their use, shape, size, application, etc:

Type of Surface. Finned and prime.

Operating Condition. Frosting, nonfrosting, and defrosting.

Refrigerant Control.

Circulation. Natural and forced convection.

Frosting Evaporators

A frosting evaporator is used when the temperature never goes above 32° F in normal operation. The evaporators that are used in household refrigeration, frozen food storage and low temperature refrigeration are in this category. This type evaporator must be defrosted either manually or automatically.

Nonfrosting Evaporators

Nonfrosting evaporators are used when temperatures remain above 32° F at all times. This type evaporator is limited to high temperature refrigeration, such as in air conditioning, process cooling, the storage of bakery products, candy, vegetables, and dairy products.

Defrosting Evaporators

The temperature of a defrosting evaporator is below 32° F when the compressor is operating and above 32° F when the compressor stops. While the unit is operating the coil frosts up, but defrosts itself when the unit stops. Because of the necessity of rapid heat flow during defrosting, forced convection evaporators are particularly adaptable to this type operation.

Bare Tube or Plate Evaporators

Bare tube or plate evaporators are normally used where the box temperature is below 32° F and in liquid cooling. These evaporators may be defrosted by scraping off the accumulated ice. This makes them ideal for use in cold storage areas and other applications where it is impossible to raise the box temperature above freezing temperature. Bare surface evaporators are also used in household refrigerators because they are easy to keep clean. Figure 13 illustrates bare tube evaporator that is used as an overhead coil or in brine tanks.

A plate evaporator is made by stamping out two plates to form tubes, and then welding the plates together. Another method of manufacture is to form a coil, cover it with plates and weld the plates together. These evaporators are used in lockers, cold storage plants, refrigerated trucks, and for fast-freezing of food. For fast freezing of foods, the evaporator serves as shelves and the food is placed directly on them. This arrangement allows a fast heat transfer from the food to the evaporator.

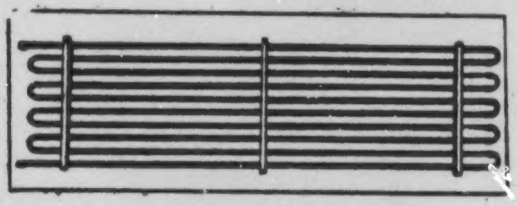

Figure 13. Bare Tube Evaporator

Finned Evaporators

Finned evaporators are made of bare tubes covered with metal fins. These fins add surface area to aid in heat transfer. Finned evaporators are used in a great number of applications. Formerly, they were used only in air conditioning and areas where the temperature did not go below 32° F. Today with the automatic defrost system these evaporators are used in application where the temperature goes down to 0° F. (See figure 14.)

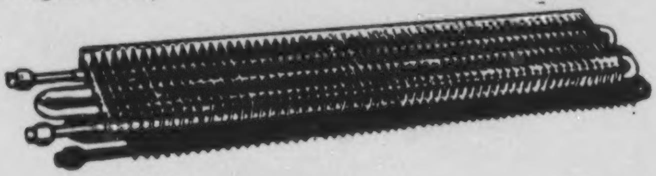

Figure 14. Finned Evaporator

Forced Convection Evaporators

Any type evaporator with a mechanical means of moving the air is a forced convection unit. They normally consist of a finned coil with a fan to force the air through the coil.

The finned coil and fan may be inclosed in a metal housing with openings for inlet and discharge air. Forced convection evaporators are very efficient as they maintain an even temperature throughout the refrigerated space.

Special Evaporator Types

The special evaporator types are modifications of the fundamental types of evaporator coils. They are designed for special uses. A few of the more important follow.

TANK TYPE COOLERS. Tank type coolers consist of an evaporator coil submerged in a tank of liquid. This liquid is known as a secondary refrigerant. The secondary refrigerant may be either plain water or a brine. If the required temperature is below 32°F, the secondary refrigerant must be a brine.

Tank type coolers are used almost universally in the manufacture of ice. Milk coolers use a tank type cooler with plain water as a secondary refrigerant. The water acts as a "cold bank" device to prevent too great a temperature rise in the low side when warm milk is placed in the cooler.

BAUDELOT COOLER. The baudelot or tubular cooler is used exclusively for the cooling of liquids. It consists of coils in a vertical arrangement. There is a trough at the top provided with holes through which the liquid flows and trickles over the coils. The liquid collects in another trough at the bottom. The refrigerant is inside the coils. This type cooler is easy to keep clean and is used extensively where aerating is a factor.

SHELL AND COIL COOLER. The shell and coil cooler is used in water coolers. The evaporator consists of an outside shell surrounding a spiral coil. The refrigerant is inside the coil and the water to be cooled is between the shell and the coil.

SHELL AND TUBE COOLER. The shell and tube cooler is used in systems using a secondary refrigerant (brine or water). The refrigerant is in the shell and the secondary refrigerant is in the tube.

SUMMARY

The heat absorbed in the evaporator is dissipated by the condenser. The condenser changes the high pressure and high temperature refrigerant gas into a high pressure liquid. (Latent heat of condensation.)

The air cooled condenser gives up its heat to air in direct contact. Two types of air cooled condensers are the natural convection and forced convection.

The water cooled condenser gives up its heat to water circulating inside tubing. Three types are the double tube, shell and coil, and the shell and tube.

The evaporative condenser is cooled by water sprayed directly on the condenser coils and evaporating. This type of condenser can be used in a climate that varies from hot to cold.

The receiver is a storage tank for surplus refrigerant in a system and allows system pump down. Two types are the horizontal and the vertical. Receivers are not installed in all systems.

The evaporator absorbs heat from the refrigerated space and changes the low pressure refrigerant liquid into a gas. Evaporators are classified according to their use, size, application, circulation, type of surface, and operating condition. Special evaporators are modifications of the fundamental types of evaporator coils.

QUESTIONS

1. What are the six factors that determine the heat transfer rate from condensers?
2. What is the purpose of the receiver?
3. What are the three groups of water cooled condensers?
4. What three events take place inside all condensers?
5. What is the operating condition of a defrosting evaporator?
6. Which condenser developes the highest head pressure?
7. How is the shell and tube condenser cleaned?
8. What cools the evaporative condenser?
9. What is the purpose of the dip tube in the receiver?
10. How full is the receiver during normal operation?

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2. Modern Refrigeration and Air Conditioning, Althouse and Turnquist
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SECTION II

REFRIGERATION COMPRESSORS

OBJECTIVE

To help you in learning the various types of refrigeration compressors, their design features, operating principles and maintenance requirements.

INTRODUCTION

The heart is a very important part of your body. It is the pump that causes the blood to circulate throughout the body. The compressor in a compression refrigeration system may be compared to the human heart. A refrigeration specialist should make a complete study of the compressor, same as a doctor makes a complete study of the heart.

REFRIGERATION COMPRESSORS

By definition, a compressor is a device that will compress gases. The function of a compressor is to remove the heat laden gas from the evaporator and raise the temperature of the gas above that of the cooling medium.

Types of Refrigeration Compressors

Not all refrigeration systems require the same type compressor. Some systems require a small volume of refrigerant moved with a high difference in inlet and outlet pressure. This difference in pressure is called differential. Some systems require a large volume of gas moved with a small pressure differential. The application and temperature range determine the type of compressor to use.

The three major types of compressors are:

1. Centrifugal
2. Rotary
3. Reciprocating

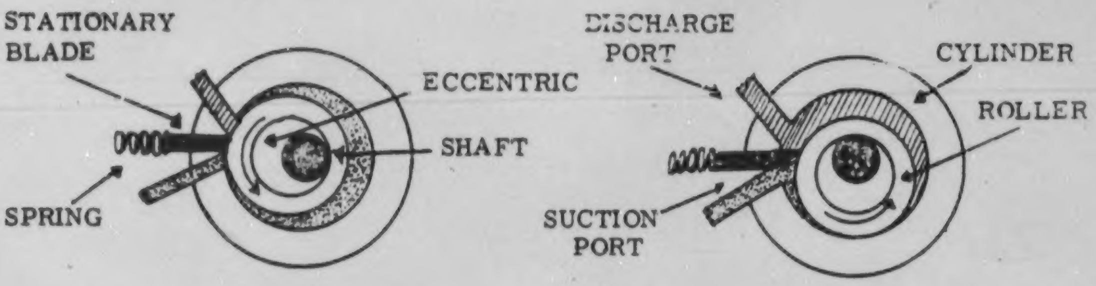
CENTRIFUGAL COMPRESSORS. The centrifugal compressor compresses the gas by action of centrifugal force. The rotating impeller draws in gas near the shaft and discharges it at a higher velocity to the outside. This velocity is converted into pressure. The velocity is a function of the speed, and to develop the required pressure, the centrifugal compressor must be a high speed machine.

Centrifugal compressors are built in one or more stages. The gas is pulled in by the first stage, compressed and discharged to the suction side of the second stage. The second stage further compresses the gas and discharges it to the condenser. The more stages of impellers in series, the greater the final discharge pressure.

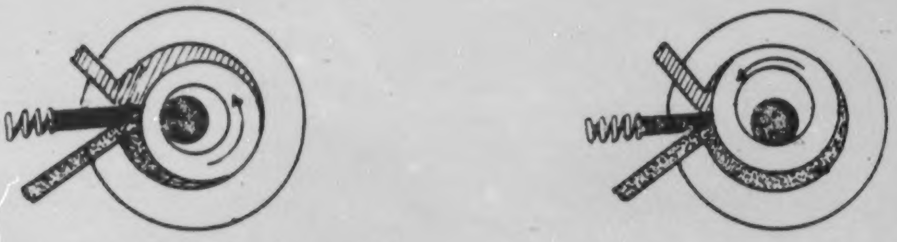
This type of compressor is used with refrigerants that have a relatively large gas volume, but small pressure differentials. Trichloromonofluoromethane (R-11) satisfies these requirements, but has a high boiling temperature. For that reason, centrifugal compressors are seldom used in systems that require temperatures below 32°F.

ROTARY COMPRESSORS. The rotary compressor compresses the gas by a squeezing action. Refrigerant gas is reduced in volume and increased in pressure. The compressor has few moving parts and can be manufactured rather inexpensively.

One type of rotary compressor is the stationary blade. This type of compressor consists of a cylinder, a roller, and a shaft. The shaft has an eccentric on which the roller is mounted. A blade is set into the cylinder so that it maintains contact with the roller. The blade is held against the roller by a spring. The suction and discharge ports are on opposite sides of the blade. The roller does not come in contact with the cylinder because an oil film seals the small clearance. Figure 15 shows the action of the compressor at various points in the cycle. The rotary compressor is used mostly in household refrigerators, but is now being made in larger sizes for commercial units.



1. START OF COMPRESSION STROKE
2. START OF SUCTION STROKE



3. DISCHARGE AND SUCTION STROKE HALF COMPLETED
4. END OF COMPRESSION STROKE

Figure 15. Action of a Stationary Blade Rotary Compressor

Another type of rotary compressor is the rotary blade. (See figure 16) It consists of a cylinder and a rotor containing a number of blades. The center of the rotor is eccentric with the center of the cylinder. There is a very small clearance between the rotor and the cylinder with the oil film maintaining the seal.

In some designs, the blades are spring loaded to hold them against the cylinder, while others depend on centrifugal force. As the rotor turns, the suction gas between the adjacent blades is reduced in volume and increased in pressure and is discharged at the end of the revolution. These compressors are usually operated at motor speed in order to reduce the size of the unit. When a rotary compressor is idle, the oil film between the rotor and the cylinder is severed. The high pressure gas would then flow back into the low pressure side. A check valve must be provided in the suction line of the compressor to prevent the hot, high pressure gas from backing up into the evaporator. The equalizing of pressure within the compressor is an advantage because it allows easy starting.

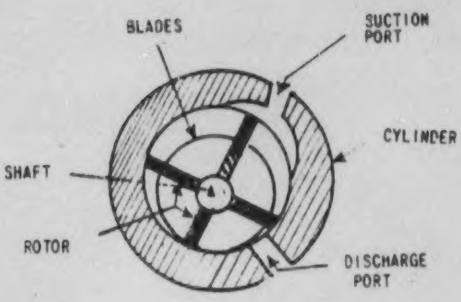
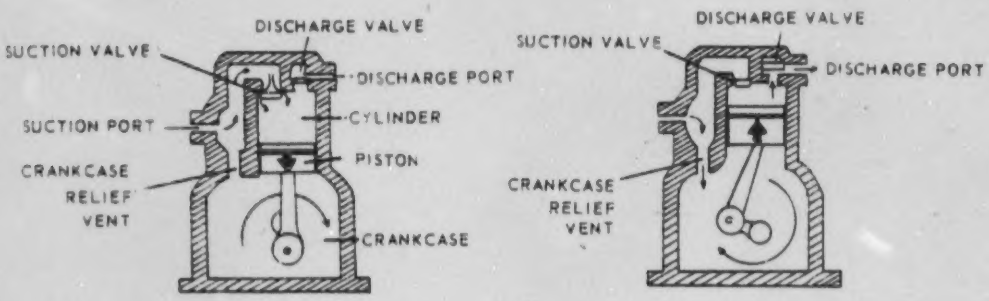

BLADES
SUCTION PORT
CYLINDER
SHAFT
ROTOR
DISCHARGE PORT

Figure 16. Rotary Blade Compressor

RECIPROCATING COMPRESSORS. The most common refrigeration compressor used today is the reciprocating type. It is used with refrigerants that have a low volume of gas per pound and a high differential, such as R-12, R-22, and ammonia. The reciprocating compressor is dependable, durable, and easy to maintain. (See figure 17.)


DISCHARGE VALVE
SUCTION VALVE
DISCHARGE PORT
SUCTION PORT
CYLINDER
PISTON
CRANKCASE RELIEF VENT
CRANKCASE
DISCHARGE VALVE
SUCTION VALVE
DISCHARGE PORT
CRANKCASE RELIEF VENT

A. Suction Stroke

B. Discharge Stroke

Figure 17. Reciprocating Compressor

Operating Principle. To evaluate compressor performance better, the refrigeration specialist must understand the operating principles of compressors.

The piston at the top of its stroke is at top dead center. Both discharge and suction valves are closed. As the piston moves downward, the suction valve opens and gas flows into the cylinder until the piston reaches the bottom of its stroke. The piston is at bottom dead center and both valves are closed again. As the piston starts back up, the pressure in the cylinder rises until it is above the pressure in the high side, thus opening the discharge valve. The piston can then force the gas in the cylinder out into the high side. The piston continues to move upward until it reaches top dead center. At this point the discharge valve closes and the cycle is completed.

Compressor Maintenance

If the compressor does not operate correctly, the system will fail to do its job. This could cause the loss of food, damage to equipment or personal discomfort. Any one of these result in added expense to Air Force operation.

One of the symptoms of a defective compressor is noisy operation. This could be caused by a loose pulley, worn or damaged pistons, worn connecting rods, or improper lubrication. Normally, a loose pulley only requires tightening while defective pistons or connecting rods require a complete overhaul. Improper lubrication, if found in time, would require only the adding of oil. Before adding oil, always check for leaking gaskets or shaft seals.

If high suction pressure is noticed, the most likely cause is a leaking suction valve. To check for leaking suction valves, front seat the suction service valve and observe the low side manifold gage. If the compressor cannot pull this small volume down to 20" hg, the suction valves are defective. This can be corrected by installing a new valve plate assembly. If a new valve plate assembly is not available, the old valve plate may be lapped and new valves used. When lapping a valve plate, use a "figure 8" motion and fine lapping compound.

During the inspection of a system, if a low head pressure is noticed, the most likely cause is leaking discharge valves. Other items to check when inspecting the compressor is the tension and alignment of the drive belt. The drive belt may be checked by turning the unit off and placing your finger on the center of the belt. If the tension is correct, you should be able to move the belt up and down one-half inch on small units and one inch on large units. The tension of belts is very important. Loose belts slip and wear quickly; belts that are too tight will stretch, weaken and eventually break.

The alignment of the flywheel and motor pulley is very important to good operation and belt life. All belts should run straight and true without vibration. Check to make sure that the motor shaft is parallel with the compressor shaft.

These are only a few of the things that you should know about compressors. Many other troubles might develop, but as your experience in refrigeration grows, your ability to analyze and correct these problems will increase.

SUMMARY

The compressor is the heart of the compression refrigeration system. It causes the refrigerant to flow through the system components by compressing the low pressure and low temperature gas from the evaporator into a high pressure and high temperature gas.

There are three types of compressors with each having a different principle of operation. The centrifugal compressor compresses the gas by centrifugal force; the rotary compressor by a positive displacement squeezing action; and the reciprocating compressor by positive displacement of a piston reciprocating in a cylinder.

The shaft seal is installed in open type compressors to form a leak-proof seal between the compressor body and the rotating shaft. Four types are the stationary bellows, rotating bellows, replacement and the diaphragm.

Compressors will give years of dependable service with proper maintenance. If the compressor does not operate correctly, the system will fail.

QUESTIONS

1. What is the principle of operation of the centrifugal compressor?
2. Why is the discharge valve spring loaded?
3. What is the purpose of the shaft seal?
4. Name the three types of compressors.
5. What is staging in centrifugal compressors?
6. Which compressor uses a blade to separate the low from the high pressure side?
7. What would cause excessive noise in a reciprocating compressor?
8. What would be the cause of high suction pressure in a reciprocating compressor?
9. What is the purpose of the valve plate?
10. Which compressor is used with R-11?

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1. AFM 85-18, Maintenance and Operation of Refrigeration, Air Conditioning, Evaporative Cooling, and Mechanical Ventilating Systems
2. Data Book, American Society of Refrigerating Engineers
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SIMPLE REFRIGERATION SYSTEM

OBJECTIVE

To help you in learning how to determine the correct tubing size for refrigeration systems, to assemble a simple refrigeration system, and the methods for evacuating and charging a refrigeration system and checking it for leaks.

INTRODUCTION

A simple refrigeration system is composed of four basic units: Compressor, condenser, refrigerant control, and the evaporator.

The proper installation of these components is necessary to obtain satisfactory and trouble-free operation. Careful attention to details and good workmanship pay dividends in better appearance and operation. Each installation should be carefully planned and sketched, and a list of materials should be compiled. These steps will save time and prevent costly changes on the job.

After the refrigeration system has been assembled, the air must be removed, the entire installation must be tested for leaks, and the proper amount of refrigerant must be added. The success or failure of the installation depends on the thoroughness and care with which these things are accomplished.

SAFETY WHILE WORKING ON REFRIGERATION EQUIPMENT

The following rules must be observed to prevent personnel injury or damage to equipment:

1. Be careful around exposed moving parts. Do not get your fingers caught in a fan, pulley, or gear train.
2. When disassembling components, place parts well back from edge of work bench to prevent injury to feet from falling objects or damage to equipment.
3. Pick up tools, pieces of tubing, etc., from floor.
4. Be careful of pointed tools, especially when fabricating tubing.
5. Watch where you point the flame when soldering or leak testing.
6. Wipe up spilled oil immediately.
7. Do not use a sharp pointed instrument to scrape ice from an evaporator.
8. Be sure the high pressure safety switch is not set above proper limits.

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ASSEMBLY OF A SIMPLE REFRIGERATION SYSTEM

The tubing work may be started at either the evaporator or the compressor. The size of lines must first be determined. When installing the suction line two things are very important, pressure drop between components and oil return. Pressure drop between components should not exceed 2 psi as it will cause starving of compressor affecting it's pumping capacity. When excessive pressure drop is encountered the lines should be checked for sharp bends, fittings and long lines of tubing. In normal installation the size of line will be the same as the fittings on the compressor but where the lines are over 25 feet in length the next size larger line should be used. The oil return to the compressor is accomplished by the movement of gas in the line. If the line is too large the oil will be slow in returning to the compressor. This line should, if possible, always slant downward to the compressor to avoid forming an oil trap. The size of the liquid line should be of sufficient size to ensure full refrigerant flow to the refrigerant control at the highest heat load.

The tubing connections between the evaporator and compressor should be run in the most direct manner possible and should be supported so that there is no strain on the tubing. The supports should be close enough together so that there will be no sagging.

In connecting two units together with copper tubing it may be necessary to form a loop or bend in the tubing to absorb any vibration. Failure to do this could cause work hardening and the tubing to break. The correct size for the loops radius is 5 to 10 times the diameter of the tubing used.

Soldering Refrigeration Lines

When heat is applied to copper in the presence of air, copper oxides form on both the exterior and interior tubing surfaces. When the system is put into operation these oxides flake off and circulate through the system. They stick in the refrigerant controls, the compressor valves, and on the cylinder walls.

Oxides can be prevented by isolating the section of line being soldered and drifting dry nitrogen gas through it at a rate of 200 feet per minute. The nitrogen will replace the air inside the tubing and oxides cannot form. The nitrogen is inert and will not combine with the copper. Pressure in a nitrogen cylinder at room temperature is about 2400 p.s.i.g., far above the bursting pressure of refrigeration system components. A pressure reducing valve must be used when connecting a nitrogen cylinder to a refrigeration system.

Use a soldering flux of the correct type. Avoid those that contain acid and ammonia. These compounds have a harmful effect on copper.

Soldering fluxes are chemically active and reasonable care must be observed. Keep the flux out of the inside of the tubing. The way heat is applied can draw flux into the tubing. Make a few test joints to observe the flow of solder and flux. Saw the test joint to expose the longitudinal section. This will indicate the correct amount of heat, solder, and flux to use and also the correct application of heat.

Flux should be applied sparingly to the tube surface before the joint is assembled. When applying flux, keep it well back from the end of the tube.

Apply the heat evenly to the joint until the flux begins to melt. Then apply the heat around the circumference of the joint until the flux is drawn into the joint. Heat the tube until it is hot enough to melt the solder to insure drawing the solder well into the joint. Do not allow the flame to melt the solder by direct contact.

Never attempt to solder a leak in a line that contains a small amount of refrigerant gas. There may not be enough pressure to indicate on the gage, but when heat is applied to the line, the refrigerant gas expands and the pressure increases enough to blow the melted solder out of the joint. Vent the tubing to the atmosphere before applying heat.

SEPARATING SOLDERED JOINTS. When servicing a refrigeration system, it is frequently necessary to separate a soldered connection, repair a leak, or replace some component. Never apply heat to a line that contains refrigerant pressure. The hazard of line rupture or refrigerant propelled molten solder is always present.

Do not unsolder a connection in a line that is under a vacuum. Not only air and moisture, but also the melted solder will be drawn into the system. The solder will form into small balls that will clog the strainer and refrigerant control valves and may damage the compressor.

Some local oxidation will be caused by the application of heat. Clean each of the mating parts before resoldering the connection.

TESTING FOR LEAKS

Leaks are one of the major refrigeration troubles because refrigerant is lost and air with moisture may enter the system. Air and moisture are serious contaminates which may cause the oil and refrigerant to break down and form corrosive products.

Charge the system for a leak test. The test pressure in small installations may be obtained with the refrigerant used in the system. In large systems it is sometimes advisable to test the system at pressures greater than two or three times normal operating pressure by using nitrogen or carbon dioxide.

Always use a pressure reducing valve when pressure checking with nitrogen or carbon dioxide. Nitrogen produces a pressure of 2400 p.s.i.g. and carbon dioxide produces a pressure of 800 p.s.i.g. at normal room temperatures.

Never use oxygen as a pressure booster. Oxygen is an oxidizer and will cause a violent explosion in the presence of oil.

Charge the system with sufficient refrigerant to maintain a pressure of 60 PSIG throughout the system. After the pressure has stablized, leak test every connection and joint.

A leak in a halocarbon system may be detected by the use of a halide leak detector. The detector fuel may be either propane, alcohol or acetylene. Air for combustion is drawn in through a hose at the base of the burner. The flame burns through a copper plate to help break down the refrigerant vapor.

The detector search hose is held near the suspected leak and if any refrigerant is present, the flame color changes to indicate a leak. This type of leak detector is capable of detecting the presence of refrigerant gases in quantities as low as 20 parts per million or one pound of refrigerant leaking out in seven years.

To use the halide leak detector, explore each joint in the system. Explore around each gasketed surface, soldered or brazed joint and threaded connection. Small leaks may produce a very slight change in the color of the flame.

Always use a pressure reducing valve when pressure checking with nitrogen or carbon dioxide. Use a relief valve in the charging line when pressurizing a system. This relief valve must be set low enough to eliminate the possibility of rupturing some part of the refrigeration system.

Always use a check valve in the refrigerant line when pressurizing with an inert gas. This will eliminate the possibility of contaminating the refrigerant in the cylinder.

Never use oxygen as a pressure booster. Oxygen is a very active gas and may cause an explosion in the presence of oil.

REPAIRING LEAKS

Leaks are usually found at soldered or brazed joints, flare connections, gasketed joints, and seals. When a leak is found, mark it and continue to check the complete system before making repairs.

If a soldered or brazed connection is leaking, vent the line to the atmosphere and resolder or braze. If the leak is around a threaded connection, it is usually better to completely remake the connection using a good pipe compound. It may be possible to stop the leak by tightening the connection.

If the leak is at a flare connection, it is usually best to remake the flare. It may be possible to stop the leak by tightening the flare nut. However, over-tightening of the flare nut will weaken the flare and it may break after being in operation a short time. Tightening the flare nut will not correct a poorly made flare.

Where the leak is through a gasketed surface, disassemble the two mating surfaces and remove the old gasket. If the metal surfaces are scratched or warped, they must be lapped. The best procedure is to use a lapping block, but if one is not available use a piece of plate glass.

After the metal surfaces are clean, apply a thin coat of refrigerant oil, use a new gasket and reassemble. Correctly mated surfaces should not require the use of gasket compounds.

If a leak is found at a seal, replace the seal. Under emergency conditions it is permissable to lap the seal surfaces. However, this procedure should be used only for temporary repairs.

The number of leaks in the system can be reduced by following these very important steps.

1. Improve your soldering and brazing techniques. This includes the correct method of applying the heat, cleaning procedures, use of fluxes, and the correct type and amount of solder.
2. Use bends in the tubing or vibration eliminators to reduce vibration.
3. Support the tubing to reduce undue stresses.
4. Use soldered joints instead of flared connections if possible.
5. Always use a good thread compound when making threaded connections.
6. Most important of all, use good workmanship in everything you do. A system that appeals to the eye usually operates efficiently.

EVACUATING

Newly installed systems and existing systems that have become contaminated with moisture and foreign gases must be evacuated before they will perform properly. The evacuating procedure is performed by using a vacuum pump.

Double Evacuation

Approximately 29/30 of the original air mass is removed when the system is reduced to a 29 inch vacuum. Pressurizing to 60 psi and then re-evacuating will reduce the air mass to approximately 1/900 of its original amount. Under these conditions the system should be relatively free from moisture and foreign gases.

Under emergency conditions the system compressor may be used to evacuate the system. However, refrigerant compressors are not designed for high vacuums and continued use under high vacuums will damage the compressor.

Care of Vacuum Pumps

The purpose of the vacuum pump is to remove air and water (in the form of vapor) from the refrigeration system. During the evacuating procedure the water vapor and the oil in the pump come in contact with each other. The oil will absorb the water vapor until the vapor pressure of the water in the oil is so high that the pump cannot maintain a high vacuum. The oil in small vacuum pumps should be changed after approximately 10 hours of operation.

Oil that contains a large amount of absorbed moisture loses its lubricating properties. A large number of vacuum pumps are damaged each year because the oil has not been changed often enough.

When evacuating a large system or where the vacuum pump is used in the shop under continuous operation, a cold trap between the refrigeration system and the vacuum pump will eliminate the water vapor from coming into contact with the vacuum pump oil.

CHARGING THE SYSTEM FOR OPERATION

There are two methods of charging a system. After a little experience, it is easy to determine which method is best suited for each application. These two methods are vapor charging and liquid charging. Vapor charging is used on small systems, while liquid charging is usually used on large systems.

It is sometimes difficult to determine when a system is correctly charged. No one method will work in all applications. Each system, the units in it, its temperature range and application, must be considered when determining the correct refrigerant charge.

The following guide lines will help you to determine the correct charge in various systems. Experience, trial and error are necessary before you become competent in determining the correct charge in a refrigeration system.

Sight Glass in the Liquid Line

The most common method of determining the correct charge in small systems is the use of a sight glass in the liquid line. If there are no bubbles in the sight glass, it is assumed that the system is correctly charged. However, this assumption can be wrong. If the sight glass is located near the outlet of the receiver, a restriction in the liquid line may reduce the flow of refrigerant enough to eliminate bubbles in the sight glass even if the system is only half charged. If the sight glass is located near the expansion valve, a restriction in the liquid line will cause bubbles in the sight glass even if the system is overcharged. The use of a sight glass at the outlet of the receiver and another at the inlet of the expansion valve will give a good indication of both the system charge and possible restriction in the liquid line.

Sight Glass in the Receiver

A sight glass in the receiver will indicate the amount of liquid refrigerant in the receiver. A system is correctly charged when the unit is operating normally and the receiver is 1/4 to 1/3 full.

System Without Sight Glass

It is difficult to determine the correct charge of refrigerant in a system without a sight glass. The following steps are helpful in determining the correct charge; however, they are only indications.

1. Install the manifold gage assembly.
2. Attach a thermometer to the evaporator outlet.
3. Run the compressor and after about ten minutes, read both gages and the thermometer.
4. Record these readings.
5. Add refrigerant as a gas into the low side.
6. Close the refrigerant cylinder valve.
7. After operating the unit about ten minutes, read both gages and the thermometer.
8. Record these readings and compare them to the readings in step 4 above.
9. Repeat steps 3 through 8 until there is no change in the reading.
10. Allow enough time for the system to reach equilibrium and then read the thermometer.
11. Convert the thermometer reading to refrigerant saturation temperature. Use the refrigerant temperature pressure relationship chart, allow 2° for temperature difference through the wall of the tubing. The suction pressure reading and the saturation temperature of the refrigerant should correspond.
12. Add a small amount of refrigerant and observe the thermometer for any change. No changes indicate that full liquid flow is being supplied to the expansion valve.

Critical Charged System

A critically charged system is charged by weight. Charge the system on a weight basis according to the manufacturer's specifications. Use a scale or a charging panel to measure an exact weight of refrigerant.

There are several other methods of determining the correct charge in a refrigeration system. They all involve the pressure, temperature, and frost line at various points in the system. These methods will work in some cases, but in others, they give a false indication. Most of these shortcut methods should not be used until you have considerable experience.

SUMMARY

A simple refrigeration system is composed of four components and interconnecting refrigerant lines. All components must be installed in the proper sequence with the correctly sized tubing.

The refrigeration system must be free of leaks. After a system is fabricated, a leak test must be made. All leaks are located, repaired and retested.

Air and moisture in a refrigeration system may cause system failure. To prevent this, the system is evacuated with a vacuum pump to remove all contaminating gases.

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The last step in fabricating is to charge the system with refrigerant. The most common method of determining a full charge is the sight glass in the liquid line.

QUESTIONS

1. List, in sequence, the four components of a simple refrigeration system.
2. How can oxides be prevented when soldering a line?
3. How does a halide leak detector indicate a leak?
4. How is a leak at a flare connection repaired?
5. Why is a system evacuated twice with a vacuum pump?
6. How is the sight glass in the liquid line used when charging a system?
7. What determines a full charge in a critical charged system?
8. How does an excessive pressure drop in the suction line affect the system?
9. Which soldering fluxes should not be used with copper tubing?
10. Why is oxygen not used as a pressure booster?

REFERENCES

1. Modern Refrigeration and Air Conditioning, Althouse and Turnquist
2. Commercial and Industrial Refrigeration, Nelson
3. Refrigeration, Air Conditioning and Cold Storage, Gunther
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COMPRESSOR CHECKS AND TROUBLE ANALYSIS

SECTION I

COMPRESSOR CHECKS

OBJECTIVE

To help you in learning to check and troubleshoot refrigeration compressors.

INTRODUCTION

Troubleshooting a complete refrigeration system is a long and complicated procedure. To aid in learning troubleshooting, only a small part of the procedure will be covered at a time. Section I of this study guide covers compressor checks such as: shaft seal checks, compressor valve checks, oil level check, and operational checks.

FUNCTIONS OF THE REFRIGERATION COMPRESSOR

A brief review of the purpose and function of compressors will aid the serviceman in evaluating performance and diagnosing malfunctions.

The compressor is a pump similar to the human heart; it circulates the refrigerant through the various lines and components in the refrigeration system.

The compressor has two main functions:

1. To remove the heat laden vapors from the evaporator.
2. To compress the heat laden vapors (gas) from a low pressure/low temperature to a high pressure/high temperature.

The temperature of the gas (as it flows into the condenser) must be higher than the temperature of the cooling medium. This allows the high pressure/high temperature gas to lose its heat to the cooling medium and condense into a liquid.

CHECKING A REFRIGERATION COMPRESSOR

Before attempting to determine the cause of a malfunction in a refrigeration compressor, make a visual check of the compressor for evidence of abuse or oil leaks. Pay particular attention to the shaft seal and the head and valve plate gaskets. After completing the visual check, install the manifold gage assembly and perform an operational check. During the operational check, observe the low and high side gages for abnormal pressures and check the compressor for abnormal noises or vibration.

Noise and vibration can be caused by such things as: broken valves, a broken piston, badly scored crankshaft, faulty connecting rod, or burned out bushings or bearings. It may be necessary to disassemble the compressor before you can determine the exact cause of the malfunction.

Suction Valve Check

The valves in modern compressors are designed to give years of satisfactory performance. However, they will eventually wear out and leak. A leaky suction valve is usually caused by abnormal wear, pitting, copper plating, foreign matter stuck under the valve, or in very rare cases, a broken valve.

A high suction pressure and a low discharge pressure indicates an inoperative suction valve. To check for a leaky suction valve, front seat the suction service valve and operate the compressor. If the compressor will pull a vacuum of 20 inch Hg, the valve is satisfactory. If the compressor does not pull the correct vacuum, it will be necessary to replace the valves and valve plate. In emergencies, it is permissible to lap the valve seats instead of changing the complete valve plate.

Discharge Valve Check

The same things that cause the failure of suction valves can also cause failure of the discharge valves. However, the discharge valves are also subjected to two other major causes of malfunctions which are:

1. Operating the system with the discharge service valve front seated. This is usually caused by inexperienced personnel trying to service refrigeration systems.

2. Pumping liquid. Refrigeration compressors are designed to pump vapor only. If a slug of liquid refrigerant or oil gets in the cylinder, the discharge valve may be damaged when the piston tries to force the liquid through the valve.

The discharge valves of small, slow speed compressors may be checked by front seating the discharge service valve. Operate the compressor intermittently (ON and OFF) until the discharge pressure reads a minimum of 150 PSIG. Do not exceed the setting of the high pressure safety switch. Stop the compressor and check the high side manifold gage. A rapid drop in pressure indicates a leaking discharge valve.

Shaft Seal Checks

Shaft seals are a constant source of trouble in an open type compressor refrigeration system. The hermetic compressor was designed as a means of eliminating the shaft seal.

The purpose of the shaft seal is to provide a gas tight seal between the compressor body and the rotating shaft. Since parts of the shaft seal move, there will be some wear and eventually some leakage. A little leakage can be tolerated, but if it is necessary to add refrigerant more often than once a year, the shaft seal should be replaced.

Oil around the shaft seal indicates a leak. However, mere presence of oil does not mean that the shaft seal has to be changed. One manufacturer designs shaft seals to leak a little oil.

There are two checks to be made when a leaky shaft seal is suspected. They are the equalized pressure check and the operational pressure check. The equalized pressure check is performed by stopping the compressor and allowing the low side pressure to equalize with the high side pressure; check the shaft seal with a leak detector. It may be necessary to cap the center line port of the manifold gage assembly and open the low and high side manifold hand valves to allow the pressure to equalize more rapidly. If you do not find a leak during the equalized pressure check, perform an operational pressure check. Operate the system until both the high and low side pressures are normal; check the shaft seal with a leak detector.

Compressor Oil Level Check

Oil is necessary for the lubrication of the compressor. It has a tendency to leave the compressor and migrate throughout the system, leaving a thin film of oil on the inside of all the pipes and tubing. This oil film reduces heat transfer to some degree.

The oil in a refrigeration system does not burn, wear out or disappear. Once oil is placed in a system, it stays there unless it leaks out.

Do not add oil just because the oil level in the compressor is a little below the correct level. If the oil has not leaked out it is still in the system and will eventually return to the compressor.

The compressor oil should be checked after repairing a leak or when installing a new compressor. After a compressor has set for any period of time, refrigerant has a tendency to condense and dissolve in the oil. Before checking the oil, operate the system until the compressor body becomes warm. This will cause any dissolved refrigerant to boil out of the oil.

Semi-hermetic compressors and large tonnage compressors are equipped with oil level indicators. The manufacturer's specifications should be used to determine the need for oil in these units.

SUMMARY

When a refrigeration compressor malfunctions, a visual check should be made. Check the shaft seal and all gaskets for evidence of abuse or oil leakage.

If the compressor can be operated, install the manifold gage assembly and perform and operational check. Observe the gage pressures and check the compressor for abnormal noise and vibration.

When the low and high side pressures are abnormal, the compressor valves may need replacing. Perform a suction valve check and a discharge valve check.

Oil around the shaft seal indicates a leak. Operate the compressor and check the seal with a halide leak detector. Check again with pressures equalized.

The compressor oil should be checked after repairing a leak or when installing a new compressor. Do not add oil unless necessary as it will leave the compressor and reduce heat transfer.

QUESTIONS

1. What suction pressure reading indicates an unsatisfactory suction valve?
2. What checks are performed on the compressor shaft seal?
3. What can cause noise and vibration in a compressor?
4. What does high suction pressure and low discharge pressure indicate?
5. When should the compressor oil be checked?
6. What type of compressor eliminates the shaft seal?
7. Which compressors are equipped with oil level indicators?
8. What normally causes failure of compressor valves?
9. What is usually damaged when liquid gets into the compressor cylinder?
10. What indicates a leaking discharge valve during the discharge valve check?

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SECTION II

TROUBLE ANALYSIS

OBJECTIVE

To help you in learning to analyze, locate, and determine remedial action to eliminate malfunctions in a simple refrigeration system.

INTRODUCTION

This study guide is limited to those troubles found in a simple refrigeration system, such as: compressor noise, vibration, high head pressures, restrictions, low charge, and refrigerant component troubles. The more complex troubles will be covered in later blocks of the course.

Trouble analysis is an organized process of elimination of troubles. The first step to follow is to install the manifold gage assembly and perform an operational check. In some cases, it is possible to determine the malfunctions immediately, while in other cases you may have to check several components before determining the exact trouble. A few minutes spent in observation and analysis may save hours of work later.

TYPES OF TROUBLES

Refrigeration troubles usually can be classified within one of the following categories:

1. Electrical
2. Refrigerant control
3. Refrigeration

Electrical troubles can cause many problems. A knowledge of refrigerant controls is essential before attempting to troubleshoot these devices. The troubles discussed in this text will be limited to refrigeration troubles utilizing physical laws and heat transfer fundamentals. Most refrigeration troubles can be diagnosed within the scope of the fundamental principles of operation of a compression refrigeration system.

REFRIGERATION TROUBLES

The best procedure to use for diagnosing refrigeration troubles is to check the operating pressures by observing the gages. As long as the unit is properly designed and sized, both suction and head pressures should correspond to pressure-temperature chart readings.

Suction Pressure

Suction pressure of the system, indicated by the compound gage, should correspond to a temperature approximately 2-4°F less than the temperature of a thermometer placed against the evaporator surface.

LOW SUCTION PRESSURE. A low suction pressure can be caused by any of the following conditions:

1. Low charge.
2. Obstructed liquid line.
3. Restricted air flow over the evaporator surface.

Low Charge

A low charge will cause the following conditions:

1. Bubbles in the sight glass.
2. Hissing at the expansion valve.
3. A warm suction line.
4. Low suction pressure.
5. Low high side pressure.
6. Warm evaporator.

Since these conditions can also be caused by a restriction in the liquid line, it may be necessary to check both possible malfunctions to determine which is causing the trouble.

A refrigeration system found to be undercharged may have a leak that has allowed some refrigerant to escape. Find and repair all leaks before recharging.

Restrictions that cause low suction pressure are usually found at screens, valves, capillary tubes, and soldered joints. A restriction in the liquid line is usually indicated by a drop in temperature at the point of restriction. A total blockage of the line can usually be found very easily. However, sometimes it becomes a real problem to determine the exact location of a partial restriction. Restrictions are usually caused by dirt, wax, small pieces of metal, solder, or collapsed tubing.

After the restriction has been found the cause of the restriction should be determined and corrected. If the restriction was caused by dirt or wax, the whole system may need cleaning before returning it back to operation.

Air Passage over the evaporator. Anything that restricts the flow of air over the evaporator will cause low suction pressure. In natural convection evaporators, this is usually caused by excessive frosting or improper arrangement of the food in the box. In forced convection evaporator systems, it is usually caused by an inoperative fan or a dirty evaporator coil. A dirty filter will cause the same condition in an air conditioning system.

HIGH SUCTION PRESSURE. A high suction pressure can be caused by any of the following conditions:

1. Faulty refrigerant control.
2. Inefficient compressor.
3. High heat load.
4. High head pressure.

Inefficient Compressor. After several years of operation, the valves, rings, and pistons become worn and result in low compressor capacity. When this condition is found, repair or replace the compressor.

High Heat Load. A refrigeration system is designed to handle a specific heat load. An excessive load on the system will result in high suction pressure, high head pressure, and possible motor burn out. During initial start up the equipment must operate under an excessive load due to the warm temperature of the refrigerated space. It may then be necessary to use an additional fan to cool the compressor and condenser.

HIGH HEAD PRESSURE. Excessive head pressure will reduce the compressor capacity, cause the unit to become noisy, and increase the operating cost. High head pressure can be caused by an overcharge of refrigerant, noncondensible gas in the condenser, cooling medium too hot, flow of cooling medium restricted, or a dirty condenser.

Overcharge of Refrigerant. If the unit is overcharged, purge the excess refrigerant to the atmosphere and charge by the use of the sight glass or by weight as specified by the data plate located on the unit.

Noncondensible Gases in the Condenser. Noncondensible gas is defined as "those gases that will not condense in a normal refrigeration system." Normally, noncondensible gases are referred to as air. Noncondensible gases can enter the system during maintenance or when there is a leak in the low side and the low side pressure drops below atmospheric pressure. If air is found in the system, purge it to the atmosphere through the discharge service valve.

When air is found in the system, the low side must be checked very closely for leaks. Air in the system indicates the presence of moisture.

Cooling Medium Too Hot. Occasionally, boxes and materials are stacked in such a way that the discharge air from the condenser will be recirculated through the condenser. If it is necessary for the unit to operate in a boiler room or any hot area, it may be necessary to use a water cooled condenser.

The water temperature of a water cooled condenser is seldom too hot. It usually is cooled by recirculation through a water cooling tower.

Cooling Medium Restricted. Dirt, scale, corrosion, and algae growth will restrict water flow through pipes and tubes in water cooled condensers. Instruction later in the course will designate the procedures to be used to clean pipes and tubes in water cooled condenser systems.

Air cooled condensers should be located to avoid restricted air flow over the surface to help reduce the head pressure.

Dirty Condenser Surface. Condensers are usually coated with dust and grease films if located in mess halls, clubs and cafeterias. Condenser surfaces usually can be cleaned with a high pressure air hose, and a special cleaning compound can be used to remove grease.

LOW HEAD PRESSURE. Low head pressure can be caused by a low charge, an inefficient compressor, and extremely cold cooling medium, or an excessive amount of cooling medium over the condenser. Most refrigerant controls are designed to operate with a pressure drop of at least 60 p.s.i.g. from the high to the low side. If the pressure drop is below 60 p.s.i.g., the amount of refrigerant passing through the refrigerant control will also be reduced. This results in a starved evaporator. The head pressure can reduce to such a degree that flashing will occur in the liquid line, causing bubbles in the sight glass. This would give an indication of a low charge of refrigerant.

Low Charge. A low charge results in a reduced amount of heat removed from the evaporator. The condenser has less heat to dissipate, causing the head pressure to remain low.

Cooling Medium Too Cold. A cooling medium that is too cold occurs often in air cooled condensers installed in cold area. It may be possible to restrict the air flow through the condenser or supply air at room temperature to the condenser. Where several condensing units are being used, it may be possible to install them in an equipment room and maintain the room temperature between 70° and 100°F. This procedure is often used in supermarkets and large drug stores. In water cooled units, restricting the flow of water will usually raise the head pressure.

EVAPORATOR TROUBLES

Ice and frost on an evaporator surface forms an insulated layer, which reduces heat transfer. This will cause an increase in box temperature and possible food spoilage. Evaporators should be clean and free of excessive frost. Specially designed scrapers are used to remove frost from large plate type evaporators. DO NOT USE SHARP POINT OBJECTS TO SCRAPE ICE AND FROST FROM EVAPORATORS.

GENERAL OPERATION

The general operation of the system is very important in diagnosing refrigeration troubles. Such things as short cycling, erratic or continuous running, and abnormal frosting of the suction line should be noted and considered when attempting to determine the cause of a refrigeration malfunction.

A modern refrigeration system should be comparatively quiet. The faint hum of the motor and perhaps a subdued clicking of the compressor valves should be expected as normal. A hissing sound at the refrigerant control indicates a low refrigerant charge. Any loud noises coming from the compressor indicate a mechanical defect.

Refrigeration systems are designed to operate smoothly and free of noise and vibration. Excessive noise is usually derived from three sources: motors, compressors, and tube or pipes.

Noisy Motors

Loose mounting bolts or worn bearings will cause excessive vibration and noise as the unit operates. The suggested remedies to remove these troubles are: tighten motor mounting bolts, replace bearing and lubricate the motor according to the manufacturer's specifications.

Compressor Noise

Installed factory shipping bolts, low oil level, and excessive head pressure will cause compressors to vibrate, ping, and knock during operation. The removal of installed shipping bolts and the removal of the causes of high head pressures from the compressor will eliminate excessive compressor noise. The oil level should be checked and oil added according to the manufacturer's specifications.

Noisy Pipes and Tubes

Vibration of pipes and tubes will cause metal fatigue and failure. The installation of vibration eliminators in rigid lines and the placing of coils in flexible lines to absorb vibration will eliminate these troubles.

SERVICE CHARTS

Service charts are especially helpful to beginners in analyzing troubles. These charts should be used only as a guide. As experience and skill are obtained, the use of these charts will become less important.

SERVICE CHART NO 1

COMPLAINT: Compressor Noisy and Runs Too Much

OBSERVATIONS	POSSIBLE TROUBLE	REMEDY
Head Pressure High	1. Condenser dirty	1. Clean condenser
Suction Pressure Normal to High	2. Air to or from the condenser restricted	2. Remove restriction
	3. Condenser area poorly ventilated	3. Ventilate area or use water cooled condenser
	4. Insufficient water to the water cooled condenser	4. Remove restriction in water line
	5. Water pressure too low	5. Install larger pump
	6. Supply water too warm	6. Use water cooling tower or evaporative condenser
	7. Air in system	7. Purge

SERVICE CHART NO 2

COMPLAINT: Condensing Unit Runs Too Long or Continuously

OBSERVATIONS	POSSIBLE TROUBLE	REMEDY
Evaporator: Entirely or partially defrosted	1. Low compressor efficiency	1. Repair compressor
	2. Belt slipping	2. Tighten belt
Suction Line: Warm	3. Low voltage	3 Report low voltage to proper activity
Suction Pressure: High	4. Condensing unit overloaded	4. Use larger condensing unit
Head Pressure: Low	5. Condenser too small	5. Use larger condensing unit
	6. Low compressor efficiency	6. Repair or replace compressor

SERVICE CHART NO 3

COMPLAINT: Unit Too Noisy

OBSERVATIONS	POSSIBLE TROUBLE	REMEDY
Compressor: Noisy	1. Compressor mounting bolts loose	1. Tighten bolts
	2. Shipping bolts installed	2. Remove shipping bolts
	3. Belt squeaks	3. Check pulley for alignment. Use belt dressing
	4. Oil level too low	4. Add oil
	5 Oil level too high	5. Remove excess oil
	6. Air in system	6. Purge
	7. Overcharge of refrigerant	7. Remove excess refrigerant
	8. Compressor worn	8. Repair or replace compressor
Motor: Noisy	1. Needs lubrication	1. Oil
	2. Brushes squeak	2. Replace motor
	3. Motor bearings worn	3. Replace motor
	4. Mounting bolts loose	4. Tighten
	5. Loose pulley	5. Tighten
Complete Unit: Noisy	1. Pipes and tubes vibrate	1. Install vibration eliminator or coils in line

SUMMARY

Trouble analysis is an organized process of elimination of possible troubles. Install the manifold gage assembly and operate the system if possible. Check the pressure readings with a temperature-pressure chart and thermometer.

Refrigeration troubles can be identified into specific conditions: Low suction pressure, low charge, restrictions, high suction pressure, inefficient compressor, high heat load, high head pressure, overcharge of refrigerant, cooling medium too hot or too cold or restricted, dirty or clogged condenser, low head pressure, excessive frost on evaporator, and noisy motors, compressors, and tubing.

Service charts are designed as a guide for the beginner with little experience. These charts list common complaints with related observations, possible troubles, and their remedy or repair.

QUESTIONS

1. What are the causes of low suction pressure?
2. Where are restrictions that cause low suction pressure found?
3. What are three causes of noise in compressors?
4. What are the results of a high heat load?
5. How is grease removed from the surface of a condenser?
6. What is the corrective action for a cooling medium that is too cold?
7. What is done in the event of a refrigerant overcharge?
8. Why is excessive frost on an evaporator undesirable?
9. What is the purpose of service charts?
10. What causes high head pressure?

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2. Modern Refrigeration and Air Conditioning, Althouse and Turnquist
3. Refrigeration, Air Conditioning and Cold Storage, Gunther
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WORKBOOKS 3ABR54530-III-1-P1 thr[illegible]I-4-P4

Department of Civil Engineering Training

Refrigeration and Air Conditioning Specialist

BASIC REFRIGERATION

September 1973

SHEPPARD AIR FORCE BASE

11-7

Designed For ATC Course Use

DO NOT USE ON THE JOB

81

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BASIC REFRIGERATION

Days 16 - 25

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This supersedes WB 3ABR54530-III-1-P1 thru III-4-P4, August 1972.

Dept of Civil Engineering Training
Sheppard AFB, Texas

WB 3ABR54530-III-1-P1
17 September 1973

FREEZING AND BOILING TEMPERATURES OF LIQUIDS

OBJECTIVE: To be able to determine the freezing point of water, the freezing point of a brine, and the boiling point of water.

FREEZING TEMPERATURES OF LIQUIDS

1. Determine the freezing point of water as follows:

   a. Pour water into a beaker until it is 1/4 full (see figure 1.)

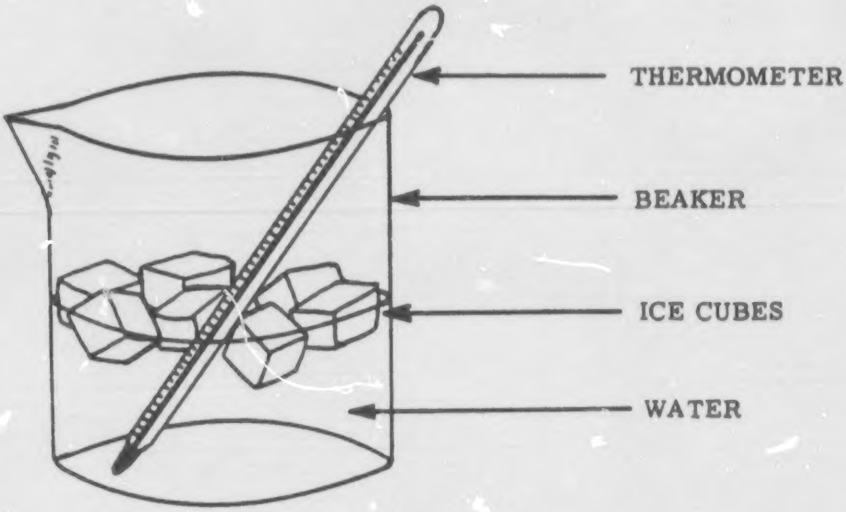

Figure 1. Determining Freezing Point of Water

   b. Add ice cubes to the beaker until it is one-half full.

   c. Place a thermometer into the ice water mixture and wait for the temperature to remain constant. When it does, the freezing temperature of the water has been reached.

   What is the temperature? __________ °F

   What is the melting point of the ice in the beaker? __________ °F

2. Determine the freezing point of a brine as follows:

   a. Add table salt (NaCl) to the water slowly and stir. Continue adding salt and stirring until the brine is saturated. Do not over-saturate with salt (maximum 23% salt by weight).

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b. Place a thermometer in the brine and wait for the temperature to remain constant. When it does, the freezing temperature of the brine has been reached.

What is the temperature ? __________ °F

BOILING TEMPERATURE OF LIQUIDS

NOTE: Liquids of different chemical compositions boil at different temperatures. This is very important in the study of refrigeration.

1. Determine the boiling point of water as follows:

   a. Pour water into a beaker until it is approximately 1/2 full.

   b. Using a Bunsen burner, heat the water until it boils.

   What is the boiling temperature of the water? __________ °F

   c. Increase the amount of flame under the beaker.

   Does the boiling temperature increase? __________

   Is it possible to increase the boiling temperature of water? __________

   If yes, explain: ____

   ____

   ____

2. Have the instructor check your work.

Checked by ______________________
Instructor

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MEASUREMENT OF HEAT AND TEMPERATURE

OBJECTIVE: To be able to determine the amount of heat contained in a BTU, how heat is measured in BTUs, how the intensity of heat is measured, and the kind of heat being added to the water, as heat is applied.

MEASUREMENT OF HEAT

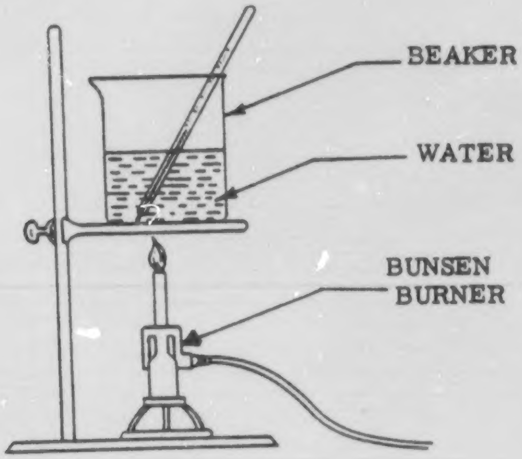


Figure 2. Measuring Heat of Water

1. Weigh or measure one pound (500 ml) of fresh water (H_2O) and pour it into a large beaker. (See figure 2.)

2. Insert a thermometer in the water and observe the temperature.

   What is the temperature? __________ °F

3. Light a Bunsen burner and adjust the flame to the size of a large kitchen match flame.

4. Place the flame under the beaker and watch the thermometer.

   NOTE: A flame about the size of a kitchen match will require approximately 30 seconds to raise the temperature of a pound of water one degree.

   When the temperature rises ten degrees, how many BTUs have been added to the water? __________ BTUs

5. Continue to heat the water until it boils.

   a. At what temperature did the water boil? ______________

   b. Did the temperature continue to rise? ______________

6. Increase the size of the flame.

   a. Did the water get any hotter? __________ Why? ____________________

   ____

   b. Is heat being added to the water? ______________________________

   c. If so, what is the name of the heat? ____________________________

   d. How much heat will have to be added to boil all the water away?

   ____

   e. Is it possible to boil water at a temperature above 212° F? __________

   f. Is so, how? ____

   ____

7. Have the instructor check your work.

Checked by ______________________________
Instructor

SENSIBLE HEAT, LATENT HEAT, AND CHANGE OF STATE

OBJECTIVE: To know the difference between sensible heat, latent heat, and be able to determine the amount of sensible heat required to change ice to water.

SENSIBLE HEAT OF ICE

1. Weigh one pound of crushed ice (if not available use ice cubes) and place it in a large beaker.

   NOTE: Ice must be below 32° F so that sensible heat can be added.

   What is the temperature of the ice? ____________°F

2. Add heat slowly with a Bunsen burner until the ice starts to melt.

   How much sensible heat has been added? ____________ BTUs

LATENT HEAT OF MELTING (Change of State)

1. Continue to add heat until all of the ice has melted.
   a. What is the temperature of the water? ____________°F
   b. How much latent heat is required to melt a pound of ice? ____________BTUs

SENSIBLE HEAT OF WATER

NOTE: Use a high temperature thermometer.

1. Add heat until the water boils.
   a. What is the temperature? ____________°F
   b. How much sensible heat has been added to the water between its freezing point and boiling point? ____________BTUs

LATENT HEAT OF VAPORIZATION (Change of State)

1. Add heat until all of the water has boiled away.
   a. How much latent heat was added? ____________BTUs
   b. What are the three states of H_2O? ______________________________,
   ______________________________ and ______________________________

2. Have the instructor check your work.

Checked by ______________________________
Instructor

IDENTIFICATION OF REFRIGERATION SYSTEM COMPONENTS

OBJECTIVE: To be able to trace the refrigeration cycle and give the function of each unit.

1. Color figure 3 as directed by your instructor.

2. Connect the trainer to the electrical power source.

3. Operate the trainer.

4. During operation of the trainer, feel of both copper lines that are connected to the compressor.

5. The warm line is the____________________.

6. The cool line is the____________________.

7. Feel the air as it leaves the condenser.

   CAUTION: DO NOT get your hand in the fan or drive belt!

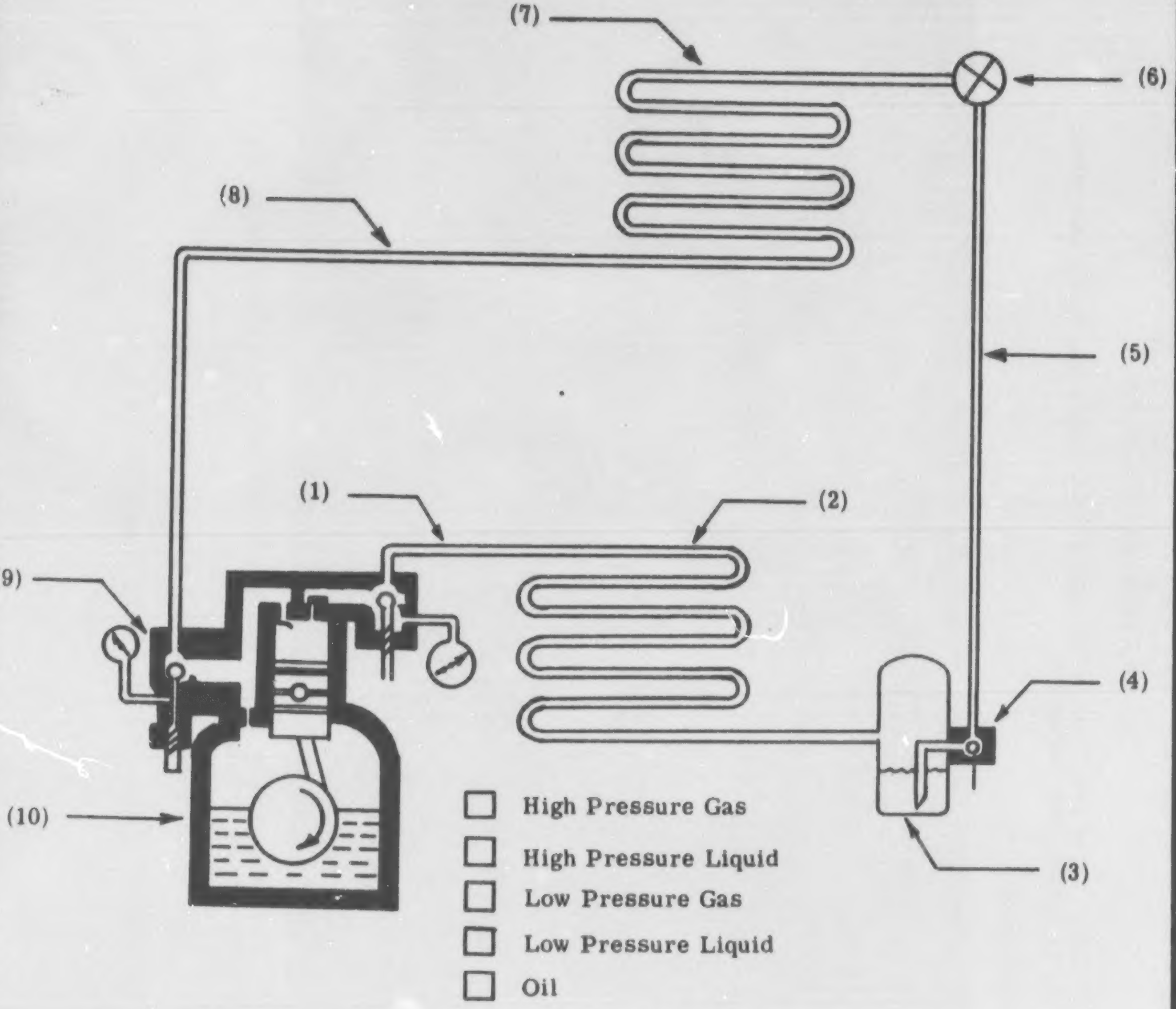
8. Where did this heat come from originally?______________________________

9. Feel the air near the evaporator.

10. Why does this air feel cool?____

11. Have the instructor check your work.

Checked by____________________________
Instructor


(7)
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☐ High Pressure Gas
☐ High Pressure Liquid
☐ Low Pressure Gas
☐ Low Pressure Liquid
☐ Oil

Figure 3.

TRANSFERRING REFRIGERANT

OBJECTIVE: To be able to use refrigerant transfer equipment, handle refrigerant cylinders, and transfer refrigerant.

PROCEDURES

1. Place the large storage cylinder in the rack in an inverted position. Why is this position necessary? ______________________________

____

CAUTION: You are handling liquid refrigerant. Be safe. Wear goggles and gloves.

2. Remove the cylinder cap and install a cylinder adapter.

3. Remove a 25-pound service cylinder from the walk-in box and weigh it using the scales provided.

4. Connect a flexible line between the storage cylinder and the service cylinder.

5. Open the valve on the storage cylinder.

6. Loosen the flexible line at the service cylinder and allow a small amount of refrigerant to escape. Why is this step necessary? ______________________________

____

7. Open valve on service cylinder.

8. Allow the refrigerant to flow into the service cylinder until the weighing scales reads 36 pounds ± 4.

9. Close the valve on the storage cylinder and then, after a short pause, the valve on the service cylinder.

10. Slowly remove the flexible line from the service cylinder.

CAUTION: This line may still contain a small amount of liquid refrigerant.

Checked by ______________________________
Instructor

LOCATION, IDENTIFICATION, AND MAINTENANCE OF CONDENSERS, RECEIVERS, AND EVAPORATORS

OBJECTIVE: To be able to identify various types of condensers, receivers, and evaporators, and list the purpose, principles of operation and maintenance requirements of condensers, receivers, and evaporators.

1. Inspect each of the listed trainers and fill out the required blanks.

   a. Small Walk-In Box

      (1) Evaporator

         (a) Type ______________________________

         (b) Advantages ______________________________

         (c) Limitations ______________________________

      (2) Condenser

         (a) Type ______________________________

         (b) Maintenance Requirements ______________________________

         ____

   b. Large Walk-In Box

      (1) Evaporator

         (a) Type ______________________________

         (b) Normal application of this type evaporator ______________

         ____

      (2) Receiver

         (a) Type ______________________________

         (b) What would happen if this receiver was installed in an upright position? ______________________________

      (3) Condenser

         (a) Type ______________________________

         (b) Principle of Operation ______________________________

(c) Application limitations ______________________________

(d) Major maintenance requirements ______________________________

____

____

c. 100-Ton Air-Conditioning System Trainer

(1) Evaporator

Type ____

(2) Condenser

(a) Type ____

(b) Location ____

(c) Why is the condenser not insulated? ____________________

____

d. 3 - Ton Air-Conditioning System Trainer

(1) Evaporator

(a) Type coil ____

(b) Manufacturer ____

(2) Condenser

(a) Type ____

(b) Method of cleaning ______________________________

(3) Receiver

(a) Type ____

e. 25-Ton Air-Conditioning System Trainer

(1) Condensers

(a) Identify the three condensers of the 25-ton trainer located outside the building:

Water Cooling Tower
1
2
3

1 ____

2 ____

3 ____

(b) Explain the major difference between a water cooling tower and an evaporative condenser:

____

____

____

(c) Of the three types of condensers installed on the 25 ton trainer, which would be the most satisfactory in:

1 Cold climates ______________________________

2 Hot and dry climates ________________________

3 Climates that varied from very cold to very hot during a year's time ______________________________

(d) What is the purpose of the duct in front of the air cooled condensers?

____

____

2. Have the instructor check your work.

Checked by ______________________________
Instructor

DISASSEMBLING A COMPRESSOR

OBJECTIVE: To be able to disassemble and repair a refrigeration compressor.

1. Remove the oil plug (1) and drain the oil.

   NOTE: This oil should be destroyed. Old oil is never used in a refrigeration system.

2. Place the compressor in an upright position and remove the ten compressor head retaining bolts (2).

3. Remove the compressor head (3) by tapping it lightly with a mallet.

4. Remove the valve plate (4) and suction strainer (5).

5. Remove the suction valves (6).

6. Remove the suction valve retaining pins (7).

7. Turn the compressor upside down and remove the ten base plate retaining bolts (8).

8. Remove the base plate (9) by tapping lightly with a mallet.

9. Remove the nut from the eccentric lock bolt (10). This nut is located between the eccentrics. You can not take out the bolt until the eccentric shaft has been removed.

10. Remove balance weight retaining bolts (11) and then remove balance weights (12).

11. Remove thrust bearing plug (13) and thrust bearing (14).

12. Remove shaft seal cover plate (15).

13. Insert a brass drift in the compressor body and drive the eccentric shaft forward 1/2 inch. This should loosen the shaft seal.

14. Remove the shaft seal (16). Make sure you remove the seal ring from the eccentric shaft and its packing.

15. Line up the Woodruff keys (17) with the key way in the compressor body (25). This key way is located in the top of the shaft seal housing.

    CAUTION: Damage to the compressor may result if the key way is not lined up properly.

16. Have the instructor check to make sure the Woodruff keys are lined up with the key way.

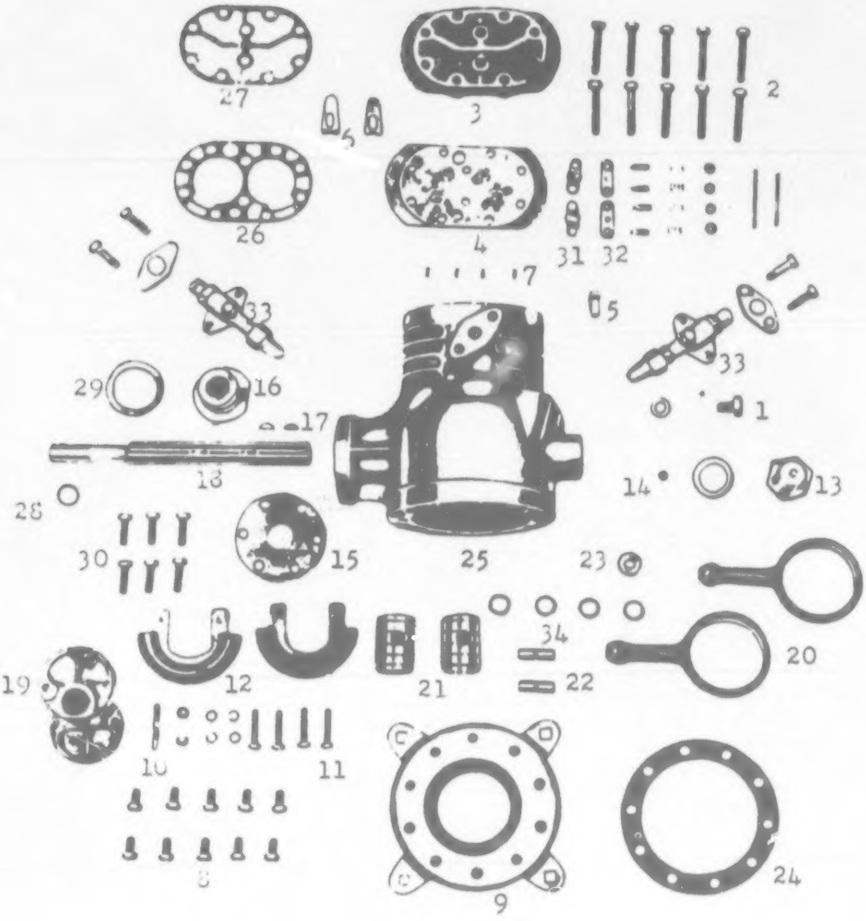
17. Tap out the eccentric shaft (18) by using a brass drift and a mallet.

18. Remove eccentric (19) and connecting rod (20).

19. Inspect piston (21), piston pin (22), connecting rod, oil check valve (23), and eccentric.

20. Have instructor check your work.

Checked by ______________________________
Instructor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24

Figure 4. Reciprocating Compressor Parts

8

REASSEMBLY OF COMPRESSOR

OBJECTIVE: To be able to identify proper tools, reassemble a compressor, and check a compressor for correct operation.

REASSEMBLY PROCEDURES

1. Lay out all parts as illustrated in figure 4.

2. Inspect each item for evidence of wear, cracks, rough handling, etc.

3. Have the instructor check each questionable item.

4. Discard rejected parts and procure new replacements as required.

5. Install connecting rods on eccentric.

   NOTE: When installing the connecting rod on the eccentric, check the direction of rotation of the compressor. The compressor should run clockwise when viewing the crankshaft from the flywheel end. This allows the oil dipper on the eccentric to pick up oil and force it to the piston pin and connecting rod bearings.

6. Insert eccentric shaft lock bolt in the eccentric. (Do not tighten the nut.)

7. Place the piston and eccentric assembly in the compressor body.

   CAUTION: Exercise extreme care when inserting the pistons in the cylinders.

8. Check the direction of rotation.

9. Insert the eccentric shaft.

   NOTE: Hold the eccentric in place and line up the Woodruff keys in the shaft with the slots in the eccentric and compressor body. After getting everything lined up, tap the end of the eccentric shaft lightly with a mallet.

10. Replace thrust bearing and thrust bearing plug.

11. With the eccentric shaft tight against the thrust bearing, adjust the eccentric to permit .010" clearance between the eccentric and the compressor body bearing surface.

    NOTE: This adjustment has an important bearing on the correct amount of seal tension.

12. Tighten the nut on the eccentric shaft lock bolt.

13. Install balance weights.

    NOTE: Use lock washers under the heads of the bolts.

14. Install base plate and gasket (24).

    NOTE: Be careful that the four compressor mounting holes in the flanges of the base plate are positioned to allow correct pulley alignment when mounted on the condensing unit base.

15. Insert the suction valve retaining pins in the top of the compressor body.

16. Replace the suction valves.

17. Install a valve plate gasket (26).

18. Install valve plate.

19. Install compressor head gasket (27).

20. Replace compressor head.

21. Install compressor head retaining bolts.

22. Install seal ring (28) on eccentric shaft.

23. Install shaft seal bellows and gasket (29).

24. Install shaft seal cover plate.

25. Install shaft seal cover plate retaining bolts (30).

26. Turn the compressor by hand with flywheel pulley to check for freedom of rotation.

27. Have the instructor check your work.

Checked by ______________________________
Instructor

3ABR54530-III-3-P1

INSTALLING A MANIFOLD GAGE ASSEMBLY

OBJECTIVE: To complete a refrigeration system drawing and install a manifold gage assembly on a refrigeration system.

CONNECTING A SYSTEM

1. Study the arrangement of the components in figure 5.
2. Place the name of each item in the space provided.
3. Draw all necessary lines to complete a simple refrigeration system.
4. Draw the position of all manifold gage valves and service valves for installation and draw lines connecting the manifold to the system.
5. Have the instructor check your work.

Checked by ______________________________
Instructor

STEPS FOR INSTALLING A MANIFOLD CAGE ASSEMBLY

1. Close both manifold valves.
2. Remove the dust cover from both compressor service valves.

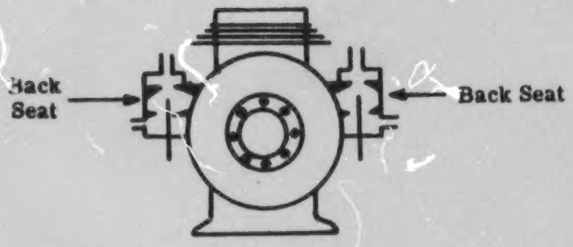
   CAUTION: Clean the area before removing the dust covers and gage port caps.
3. Place both compressor service valves in the back seat position by turning the valve stems counterclockwise.
4. Remove service valve gage port cover caps.
5. Connect the low side gage line of the manifold gage assembly to the compressor suction service valve gage port.

   NOTE: All flexible line connections should be finger-tight only.
6. Connect the high side gage line of the manifold gage assembly to the compressor discharge service valve gage port.
7. Place both compressor service valves in the gage position.
8. Slightly open each manifold valve momentarily and then close again.
9. Why is step 8 necessary? ______________________________

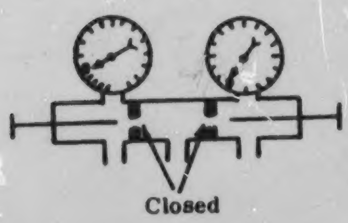
____

10. Have Instructor check your work.

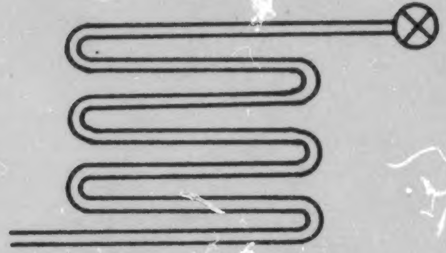
Checked by ______________
Instructor


Back Seat
Back Seat

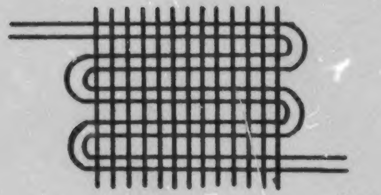
A. ______________



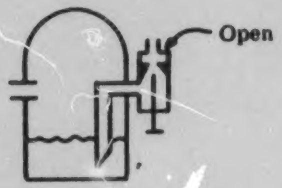
E. ______________



D. ______________



B. ______________



C. ______________

Figure 5. System Components

ASSEMBLING A REFRIGERATION SYSTEM

OBJECTIVE: To be able to draw a refrigeration system and label the units, fabricate lines and assemble a complete system.

PREPARATION FOR ASSEMBLY

1. Using your own symbols, make a sketch of the refrigeration system to be assembled and label all the units.

2. List all tubing required:

	Size	Approximate Length
a.		
b.		

3. List the number, size and type of flare nuts required:

	Size and Type	Number Required
a.		
b.		
c.		

4. Ask the instructor to check completed steps.

Checked by: ______________________________
Instructor

ASSEMBLING SYSTEM UNITS

1. Cut a piece of tubing the correct size and length to be used as a suction line.

   What would an undersize suction line cause? ______________________________

2. Flare and make a spiral loop in the suction line.

   NOTE: The radius for a loop should be 5 to 10 times the diameter of the tubing.

   Why is a loop between the evaporator and compressor? ______________________________

3. Install the suction line between the suction service valve and the evaporator outlet.

   CAUTION: Do not over tighten the flare nuts as the flare might be cut off.

   What type of flare nut must be used at the evaporator outlet? ____________________

   ______________________________ Why? ______________________________

4. Why is it necessary to always slant the suction line down to the compressor? _____
   ______________________________.

5. Attach a sight glass about six inches from the receiver in the liquid line.

   NOTE: The sight glass should be easily viewed from the front of the trainer. The dot should be to the rear.

6. Fabricate the liquid line to the inlet of the refrigerant control.

   NOTE: Place a loop in this line.

7. Have the instructor check your work.

Checked by: ______________________________
Instructor

CHARGING FOR LEAK TEST

OBJECTIVE: To charge a simple refrigeration system for leak testing.

1. Install the manifold gage assembly.

2. Close both manifold gage valves.

3. Place both compressor service valves in the gage position.

   Why should the service valves be in the gage position? ____________________

   ____

4. Connect the middle port of the manifold gage assembly to a refrigerant cylinder using a flexible charging line.

   How tight should these connections be? ____________________________

5. Put on safety goggles.

   Why is this step necessary? __________________________________

   ____

   CAUTION: Be sure that the refrigerant cylinder is in an upright position.

6. Open the refrigerant cylinder valve a minimum of 1/2 turn.

7. Loosen the middle flexible line connection at the manifold gage assembly to purge the air out of the line.

8. Tighten the flexible line connection.

9. Open both manifold valves enough to let the refrigerant from the cylinder enter the system. Both gages should indicate 60 PSIG or more.

10. Close both manifold gage valves.

11. Close the refrigerant cylinder valve.

12. Have the instructor check your work.

Checked by ________________________
Instructor

USING THE HALIDE LEAK DETECTOR

OBJECTIVE: To use the halide leak detector to leak test a simple refrigeration system.

1. Open the needle valve slightly to start fuel gas flow.
2. Ignite the gas at the detector tip.
3. Using the needle valve, adjust the flame to about an inch above the reactor plate.
4. Observe the reactor plate until it becomes heated to a cherry red color.
5. Using the needle valve, re-adjust the flame to 5/8 inch above the reactor plate.
6. Explore for leaks by moving the end of the search hose around all joints and connections.

   NOTE: The search hose must be moved slowly.

7. Observe the flame for a possible color change. A small leak will be indicated by a green flame. A large leak will be indicated by a purplish-blue flame.

   CAUTION: Be careful of any phosgene gas that may develop.

8. Have the instructor check your work.

Checked by ______________________________
Instructor

EVACUATING PROCEDURES

OBJECTIVE: To evacuate a simple refrigeration system with a vacuum pump.

1. Install the manifold gage assembly.
2. Purge any refrigerant pressure from system.
3. Connect the center flexible line to the vacuum pump as illustrated in figure 6.

   CAUTION: Be sure to connect the hose to the correct fitting or the vacuum pump may be damaged.

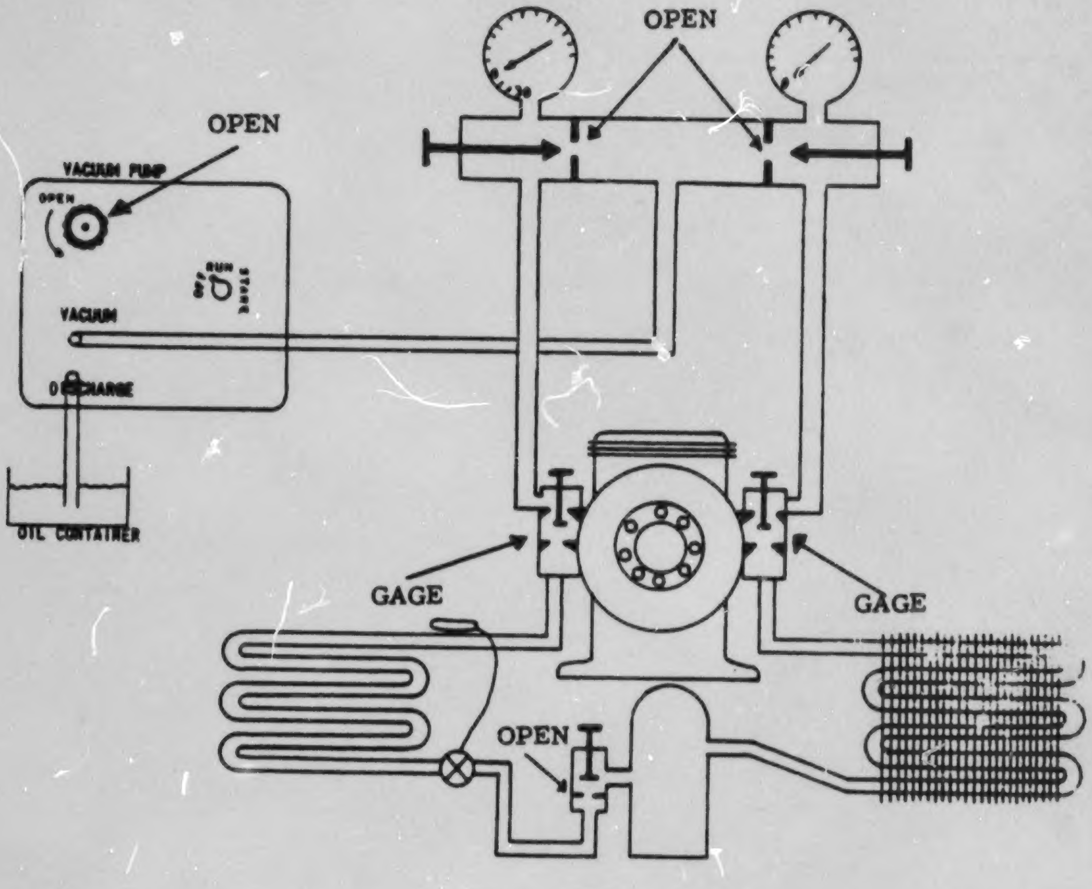

OPEN
OPEN
VACUUM PUMP
OPEN
RUN
START
VACUUM
DISCHARGE
OIL CONTAINER
GAGE
GAGE
OPEN

Figure 6.

4. Position the manifold gage valves, service valves and king valve as illustrated in figure 6.
5. To start the vacuum pump turn the start switch to the start position and then release. The switch will return to the run position.

   CAUTION: If this is not done correctly damage to the pump could result.

6. Operate the vacuum pump until approximately 29" of mercury shows on the low side gage.

7. Close both manifold gage valves.

   NOTE: If system has a leak the vacuum will not hold when the valves are closed. If the system has a leak repair it and repeat steps 3, 4, 5, 6, and 7.

8. Stop the vacuum pump.

9. Have the instructor check your work.

Checked by: ______________________
Instructor

CHARGING A SYSTEM FOR OPERATION

OBJECTIVE

To charge a refrigeration system for operation.

1. PREOPERATIONAL CHECK

a. Insure that trainer is unplugged.

b. Check for loose or frayed electrical wiring.

c. Check for loose or broken refrigeration lines.

d. Check pressure setting on high pressure control to ensure that it is not set above 200 p.s.i.

e. Insure that trainer is grounded.

2. OPERATIONAL CHECK

a. Wear protective goggles.

b. Insure that both compressor service valves are in the gauge position.

c. Insure that the king valve is in the open position.

d. Plug trainer into the 110-volt outlet.

e. Insure tools are not in a position to fall into the condenser fan and compressor fly wheel while trainer is in operation.

f. Connect a refrigerant cylinder to the center flexible line of the manifold gauge assembly.

g. Open cylinder valve one half turn.

h. Purge the air from the charging line at the center port of the manifold gauge assembly.

i. Slightly open the low side manifold gauge assembly.

j. Start the compressor.

k. Adjust the low side manifold gauge valve to maintain approximately forty p.s.i.g. on the compound gauge.

l. Observe the sight glass.

What condition is indicated by bubbles in the sight glass? ____________________

____

CAUTION: Do not leave your trainer while you are charging.

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m. As soon as bubbles in the sight glass disappear, close the low side manifold gauge valve to stop the charging process.

n. Let the refrigeration system operate for several minutes.

NOTE: If bubbles do not reappear, the unit is fully charged.

3. POST OPERATIONAL CHECK

a. Close the refrigerant cylinder valve.

b. Remove the charging line from the refrigerant cylinder.

c. Remove your safety goggles.

d. Have instructor check your work.

Checked by ______________________
Instructor

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OPERATIONAL CHECK

OBJECTIVE: To perform an operational check on a simple refrigeration system, compute head pressure, check the refrigerant charge, determine the evaporator temperature, and check the condenser temperature

1. Record position of all valves for normal operation:
   - a. Compressor discharge service valve ______________________________
   - b. Compressor suction service valve ______________________________
   - c. Receiver valve (king valve) ______________________________
   - d. Low side manifold valve ______________________________
   - e. High side manifold valve ______________________________
2. Operate the system until pressures and temperatures stabilize before proceeding to the next step.
3. Compute system head pressure.
   - a. Ambient air temperature is ____________ °F.
   - b. Head pressure should be ____________ PSIG.
   - c. Head pressure is ____________ PSIG.
   - d. Is this pressure normal at this ambient temperature? ______________________
4. Note sight glass for refrigerant charge.
   - a. Sight glass indicates the system is ______________.
5. Place thermometer on evaporator surface. Wait until temperature stabilizes. Compare converted thermometer reading with low side gage.
   - a. Reading on thermometer ____________ °F.
   - b. Reading on compound gage __________ PSIG.
   - c. If converted thermometer reading is different than low side gage what is possible trouble? ____________, ____________.
6. Check the ambient air temperature at the inlet of the condenser with a thermometer.
   - a. Temperature reading _________ °F.

CAUTION: DO NOT TOUCH CONDENSER FAN BLADE WITH THERMOMETER OR HAND!

7. Check the ambient air temperature at the outlet of the condenser with a thermometer.

   Temperature reading ____________ °F.

8. Is the condenser transferring heat to the cooling medium? ____________

   Give reason: ____

   ____

9. Check the condition of the condenser.

   a. Are the fins straight? ____________

   b. Is the surface clean? ____________

   c. Check security of mounting.

      Results: ____

   d. Check for restricted air flow.

      Results: ____

10. Have the instructor check your work.

Checked by: ______________________
Instructor

10

PUMP DOWN

OBJECTIVE: To be able to pump down a simple refrigeration system.

1. Position of all valves for system pump down:

   a. Compressor discharge service valve ______________________________

   b. Compressor suction service valve ______________________________

   c. Receiver valve (king valve) ______________________________

   d. High side manifold valve ______________________________

   e. Low side manifold valve ______________________________

2. Operate the system until the compound gage reading remains between 1 to 5 PSIG. The system is then pumped down.

   NOTE: System may have to be started and stopped a number of times before pressure remains 1-5 PSIG.

3. SHUTDOWN PROCEDURES

   a. Turn off system

   b. Unplug trainer from 110 volt power supply

   c. Back seat compressor service valves

   d. Purge and remove the manifold gauge assembly

   e. Install dust covers and port caps

   f. Clean unit

4. Have instructor check your work.

Checked by ______________________________
Instructor

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COMPRESSOR OIL LEVEL CHECK

OBJECTIVE: To be able to position service valves for an oil level check, interpret manifold gage pressures, and determine compressor oil level.

1. Install manifold gage assembly.

2. Position all valves for normal operation.

3. Purge air from the manifold gage assembly and flexible lines.

4. Operate the compressor until the compressor body is warm or until the refrigerant has been removed from the oil.

5. Turn off the compressor.

6. Front seat the suction service valve.

7. Pump the compressor crankcase down to between 1 to 5 PSIG, compound pressure gage.

   CAUTION: GOGGLES SHOULD BE WORN FOR THE NEXT STEP!

8. Remove the oil plug slowly.

9. Check the oil level in the compressor with a clean dip stick. Satisfactory oil level should range between 1-1/4" to 2-1/2" in depth (Figure 7).

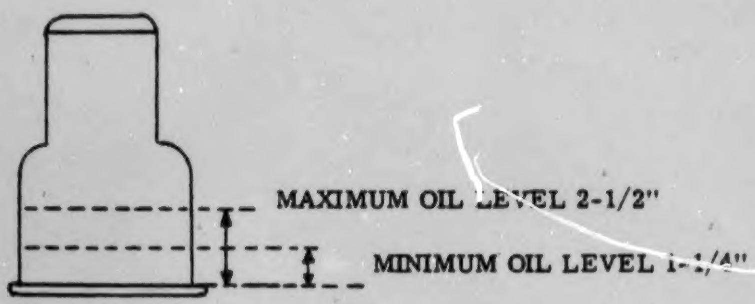

Figure 7.

10. Add oil only if necessary.

    NOTE: Do not add excessive oil to compressor. Excess oil will cause the compressor to pump oil and reduce compressor efficiency.

11. Replace oil plug loosely in the compressor.

12. Crack the compressor suction service valve momentarily from the front seat position to purge air from the compressor crankcase.

13. Tighten the oil plug. Use 3/4" box-end wrench.

14. Return the compressor suction service valve to the gage position.

15. Clean up your work area of any spilled oil.

16. Have the instructor check your work.

Checked by: ______________________________
Instructor

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COMPRESSOR VALVE CHECKS

OBJECTIVE: To be able to check compressor suction valves and discharge valves.

SUCTION VALVE CHECK

1. Install the manifold gage assembly.
2. Place all valves in the normal operation position.
3. Purge air from manifold gage assembly and flexible lines.
4. Operate the unit until the compressor body feels warm to the hand or until the refrigerant has been removed from the oil.
5. Front seat the suction service valve.
6. Operate the system until the compressor pulls down to a 20" Hg vacuum.
7. Record the suction pressure reading. ________________________________
8. If the compressor will not pull a minimum of 20" Hg, the suction valves are probably bad.
9. During normal operation, what would indicate a leaky suction valve?

   ____
10. Return the suction service valve to the gage position.
11. Stop the compressor.

DISCHARGE VALVE CHECK

1. Be sure the compressor is NOT operating.
2. With the manifold gage installed, front seat the discharge service valve and gage the suction service valve.

   CAUTION: EXCESSIVE HEAD PRESSURE CAN BLOW THE COMPRESSOR HEAD OFF IF THE HIGH PRESSURE SAFETY SWITCH FAILS!
3. Operate the compressor intermittently (ON and OFF) until a minimum of 150 PSIG pressure is indicated on the high pressure gage.
4. Watch the high pressure gage indicator needle closely. A rapid drop in pressure down to and below normal operational head pressure indicates a leaky discharge valve. A moderate drop in pressure with the needle stopping at normal operational head pressure indicates a good discharge valve.

10

5. Record your observation: ____________________

____

____

____

6. Your observation in step 5 indicates a __________ discharge valve.

7. Return the discharge service valve to the gage position.

8. Have the instructor check your work.

Checked by ____________________
Instructor

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COMPRESSOR SHAFT SEAL CHECKS

OBJECTIVE: To be able to check compressor shaft seals for leakage.

OPERATIONAL CHECK

1. Install the manifold gage assembly.
2. Position all valves for normal operation.
3. Operate the system for a minimum of 5 minutes.
4. Check the shaft seal with a halide leak detector while the compressor operates.

   CAUTION: BE CAREFUL OF ALL MOVING PARTS !
5. Watch color of flame for any change:
   a. Green - small leak
   b. Purplish blue - large leak
6. Record your observation: ______________________________

   ____

   ____

EQUALIZED PRESSURE CHECK

1. Turn off the compressor.
2. Remove the center flexible line from the manifold gage assembly.
3. Cap the center port of the manifold gage assembly with a compressor service valve gage port cap. Leave this cap loose for purging.
4. Open the high side manifold gage assembly valve momentarily to purge air from the manifold gage assembly.
5. Tighten the cap on the manifold gage assembly.
6. Slightly open both manifold gage assembly valves to by-pass pressure from high to low side of the system.
7. Note pressure readings on the compound and high pressure gages. Both gages should read equal pressure.
8. Check the shaft seal with a halide leak detector when pressures have equalized.

10

9. Record your observations: ______________________________________

____

____

10. Close both manifold gage assembly valves.

11. Carefully remove cap from the center manifold gage assembly port and install center flexible line in its place.

12. Have the instructor check your work.

13. Shutdown Procedures

    a. Turn off system.

    b. Unplug trainer from 110-volt power supply.

    c. Back seat compressor service valves.

    d. Purge and remove the manifold gage assembly.

    e. Install dust covers and port caps.

    f. Clean unit.

14. Have instructor check your work.

Checked by________________________
Instructor

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Section 1

USING THE TROUBLE ANALYSIS CHARTS

OBJECTIVE: To be able to use trouble analysis charts to locate troubles in a refrigeration system.

1. Install the manifold gage assembly.
2. Operate the unit if no hazardous condition is apparent.
3. Using the Trouble Analysis Charts in Student Study Guide 3ABR54530-III-5, Section II, fill in the information in the blank columns of the chart below.

OBSERVATIONS	TROUBLE	REMEDY
1.	1.	1.
2.	2.	2.
3.	3.	3.

10

OBSERVATIONS	TROUBLE	REMEDY
4.	4.	4.
5.	5.	5.
6.	6.	6.
7.	7.	7.

4. Have the instructor check your work.

Checked by: ______________________
Instructor

Section 2

SERVICE VALVES AND MGA VALVES POSITIONS

OBJECTIVE: Be able to position all valves correctly.

	SV		MGA		KV	Remarks
	LOW	HIGH	LOW	HIGH		
1. Charge for leak check						
2. Evacuate system						
3. Charge for operation						
4. Normal operation						
5. Pump down system						
6. Oil check						
7. Suction valve check						
8. Discharge valve check						
9. Operational shaft seal check						
10. Equalizing shaft seal						
Using compressor for evacuation						

Checked by ______________________
Instructor

ATC-SHEPPARD AFB TEX. 78-[illegible]

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER IV	BLOCK TITLE Refrigeration Controls and Accessories

1 COURSE CONTENT	2 TIME
1. Refrigerant Controls	24 (18/6) Day 26 thru 28
a. Using workbook procedures, refrigeration trainer and tools provided, remove, repair, replace and adjust an automatic expansion valve to maintain pressures from 5 to 10 PSIG. STS: 15b(1)(a), 15b(1)(b), 15b(2), 15b(3), 15b(4), 15b(5), 17c(4). Meas: W, PC	(6/2) Day 26
(1) Purpose of refrigerant controls	
(2) Types of refrigerant controls and their methods of operation	
(3) Procedures for removal and replacement of refrigerant controls	
b. Using workbook procedures, refrigeration trainer and tools provided, remove, repair, replace and adjust an internal equalized thermostatic expansion valve to maintain a superheat setting of 10±1°F. STS: 15b 1(b), 15b(2) Meas: W, PC	(6/2) Day 27
(1) Definition of superheat	
(2) Methods of operation of an internal equalized thermostatic expansion valve	
(3) Methods used to check and set superheat on a thermostatic expansion valve	
c. Using workbook procedures, refrigeration trainer and tools provided, remove, repair, replace and adjust an external equalized thermostatic expansion valve to maintain a superheat setting of 10±1°F. STS: 15b(5), 17c(4). Meas: W, PC	(6/2) Day 28
(1) Method of operation of an external equalized thermostatic ~~expansion valve.~~	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3ABR54530	16 January 1976	37

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(2) Maximum pressure drop allowed across the evaporator

(3) Methods used to troubleshoot TEV's

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-IV-1, Refrigerant Controls
WB 3ABR54530-IV-1-P1, Installation and Adjustment of Automatic Expansion Valves
WB 3ABR54530-IV-1-P2, Checking and Installing Thermostatic Expansion Valves
WB 3ABR54530-IV-1-P3, Installing a Thermostatic Expansion Valve with External Equalizer Line

Audio Visual Aids
Charts, Set, Refrigerant Controls
Transparencies, Set, Refrigerant Controls
Training Film: TF 5624a, Refrigeration Expansion Valve Manual and Automatic Operation
Training Film: TF 5624b, Refrigeration Expansion Valve Thermostatic Valve Operation
Prenarrated Slides: Metering Devices

Training Equipment
Trainer, Thermostatic Expansion Valve (12)
Trainer, Motor Controls and Refrigeration Accessories (2)
Trainer, Automatic Expansion Valve (Bellows Type) (12)
Trainer, Thermostatic Expansion Valve Tester (12)
Trainer, Automatic Expansion Valve (Diaphram Type) (12)

Training Methods
Discussion/Demonstration (7.25 hrs)
Training Film (0.5 hr)
Performance (10.25 hrs)
CTT Assignment (6 hrs)

Multiple Instructor Requirements
Safety, Supervision (2)

Instructional Guidance
Ensure that all students accomplish all preoperational checks prior to operation of trainer and place adequate emphasis on safety precautions while working on trainer. Outside Assignment: Day 26, direct students to review WB IV-1-P1; Day 27, P2; Day 28, P3.
MIR: Two instructors are required for 10.25 hours during student performance (3.5 hours in Day 26, 3 hours in Day 27, and 3.75 hours in Day 28).

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist
BLOCK NUMBER	**BLOCK TITLE**
IV	Refrigeration Controls and Accessories

1 COURSE CONTENT	2 TIME
2. Motor Controls	21 (16/5) Days 29 thru 31
a. Using workbook procedures, refrigeration trainer and tools provided, remove, clean, install and adjust a thermostatic motor control to maintain a refrigerated space temperature of 25 to 35° F. STS: 10e(5), 15a(1), 15a(2), 15a(3). Meas: W, PC	(6/2) Day 29
(1) Purpose of a thermostatic motor control.	
(2) Types of motivating devices	
(3) Term application	
(4) Operation of the thermostatic motor control	
(5) Common troubles of a thermostatic motor control	
(6) Wiring of a system utilizing a thermostatic motor control	
(7) Cleaning and adjustment procedures for a thermostatic motor control	
(8) Removal and installation procedures for a thermostatic motor control	
b. Using workbook procedures, refrigeration trainer and tools provided, remove, clean, install and adjust a low pressure motor control to maintain an evaporator temperature of 30 to 40° F. STS: 10e(5), 15a(1), 15a(2), 15a(3). Meas: W, PC	(6/2) Day 30
(1) Operating principles of pressure motor controls.	
(2) Adjustment and calibration procedures for the low pressure motor control	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
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(3) Common usage of a low pressure motor control.

c. Using refrigeration trainer and tools provided, remove, clean, install and adjust a hi pressure safety switch to the specifications outlined in workbook. STS: 10e(5), 15a(1), 15a(2), 15a(3) (4/1) Day 31
Meas: W, PC

(1) Adjustment and calibration procedures for the hi pressure safety switch

(2) Common usage of a hi pressure safety control

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-IV-2, Motor Controls
WB 3ABR54530-IV-2-P1, Installing and Adjusting Thermostatic Motor Controls
WB 3ABR54530-IV-2-P2, Installing and Adjusting a Low-Pressure Motor Control
WB 3ABR54530-IV-2-P3, Installing and Adjusting a High-Pressure Safety Switch

Audio Visual Aids
Charts, Set, Motor Controls
Transparencies, Set, Motor Controls

Training Equipment
Trainer, Refrigeration Thermal-Type Motor Control (12)
Trainer, Motor Controls and Refrigeration Accessories (2)
Trainer, Refrigeration Pressure Control Motor Switch (12)

Training Methods
Discussion/Demonstration (7 hrs)
Performance (9 hrs)
CTT Assignment (5 hrs)

Multiple Instructor Requirements
Safety, Supervision (2)

Instructional Guidance
Place adequate emphasis on safety precautions while using refrigeration equipment. Outside assignment: Day 29, direct students to review WB IV-2-P1; Day 30, P2; Day 31, P3.

MIR: Two instructors are required for 9 hours during student performance (4 hours in Day 29, 3 hours in Day 30, and 2 hours in Day 31).

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
IV	Refrigeration Controls and Accessories

1 COURSE CONTENT	2 TIME
3. Refrigeration Accessories and Trouble Analysis	33 (24/9) Day 31 thru 35
a. Using workbook and refrigeration trainer, locate and identify heat exchanger and oil separator as to their purpose, use, principle of operation, installation and maintenance. STS: 13e(1), 13e(2), 13e(3), 13e(5), 13e(6), 13e(7). Meas: W (1) Purpose of the heat exchanger (2) Types of heat exchangers (3) Removal, cleaning and installation procedures for heat exchangers (4) Purpose of an accumulator (5) Accumulator application (6) Purpose of an oil separator (7) Oil separator application (8) Procedures for removing, cleaning, charging and installing an oil separator.	(5/2) Days 31 and 32
b. Using tools provided, replace the drier on the refrigeration trainer to the specifications outlined in workbook. STS: 13e(4), 13e(5), 13e(6), 21c(5). Meas: W, PC (1) Effects of moisture in a refrigeration system (2) Purpose of a filter-drier (3) Types of filter-driers	(6/2) Days 32 and 33

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

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(4) Procedures for removing and installing a filter-drier

(5) Types of strainers

(6) Purpose of mufflers

(7) Types of pressure relief valves

(8) Vibration eliminators

(9) Surge tank operation

c. Using workbook procedures, trouble analysis chart and tools provided, troubleshoot the refrigeration trainer to locate all malfunctions introduced by the instructor and list the corrective action for each. STS: [illegible], 14f. 21c(1), 21c(2), 21c(3), 21c(4), 21a, 21d MEAS: PT, PC

(13/5) Day 33, 34, and 35

(1) Three categories of refrigeration system troubles

(2) Interpret manifold gauge pressures

(3) Restrictions

(4) Abnormal noises

(5) Odors

(6) Using trouble analysis chart

SUPPORT INSTRUCTIONAL MATERIALS

Student Instructional Materials
SG 3ABR54530-IV-3, Refrigeration Accessories and Trouble Analysis
WB 3ABR54530-IV-3-P1, Removing and Installing Heat Exchangers
WB 3ABR54530-IV-3-P2, Removing and Installing an Oil Separator
WB 3ABR54530-IV-3-P3, Removal and Installation of Driers
WB 3ABR54530-IV-3-P4, Using Trouble Analysis Charts
WB 3ABR54530-IV-3-P5, Locating and Removing Restrictions
WB 3ABR54530-IV-3-P6, Trouble Analysis Procedures

Audio Visual Aids
Charts, Set, Refrigeration Accessories
Transparencies, Set, Refrigeration Accessories

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

Training Equipment
Trainer, Refrigeration Oil Separator (2)
Trainer, Motor Control and Refrigeration Accessories (2)

Training Methods
Discussion/Demonstration (8.5 hrs)
Performance (15.5 hrs)
CTT Assignment (9 hrs)

Multiple Instructor Requirements
Safety, Equipment, Supervision (2)

Instructional Guidance
Place adequate emphasis on safety precautions while using refrigeration equipment. Outside Assignment: Day 31, direct students to review WBs IV-3-P1 and P2; Day 32, P3; Day 33, P4; Day 34, P5; Day 35, P6.

MIR: Two instructors are required during 13 hours of student performance (3 hours in Day 33, 6 hours in Day 34, and 4 hours in Day 35).

4. Measurement Test and Test Critique 2 (2/0) Day 35

STUDY GUIDE 3ABR54530-IV-1 thru -3

Department of Civil Engineering Training

Refrigeration and Air Conditioning Specialist

REFRIGERATION CONTROLS AND ACCESSORIES

January 1975

SHEPPARD AIR FORCE BASE

11-7

Designed For ATC Course Use

DO NOT USE ON THE JOB

REFRIGERATION AND AIR-CONDITIONING SPECIALIST

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IV-3	Refrigeration Accessories and Trouble Analysis	35

This supersedes SG 3ABR54530-IV-1 thru -3, and WB 3ABR54530-IV-1-P1 thru -3-P6, September 1973.
(Previous editions will be used until supply is exhausted.)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54530-IV-1
21 January 1975

REFRIGERANT CONTROLS AND ACCESSORIES

OBJECTIVE

To aid you in learning the principles of operation, installation procedure, adjustment, and trouble analysis of refrigerant controls.

INTRODUCTION

Any device used to control the amount of liquid refrigerant to the evaporator is called a refrigerant control or metering device.

In order to maintain refrigeration and air-conditioning equipment, a thorough knowledge of refrigerant controls is necessary.

You will be required to know the principle of operation, installation procedure, and adjustment of the following controls:

1. Manual expansion valve
2. Capillary tube
3. Automatic expansion valve
4. Thermostatic expansion valve

MANUAL EXPANSION VALVE

In the early days of mechanical refrigeration, expansion valves were manually operated. This type of valve may still be in use in some large industrial systems and iceplants. However, most of them have been replaced with modern type valves.

The manual expansion valve (sometimes called a hand needle valve) is regulated to meter the amount of liquid refrigerant into the evaporator manually by an attendant. A thorough knowledge of the manual expansion valve will also aid you in understanding the operation of the other refrigerant controls.

Operation of the Manual Expansion Valve

Note in figure 1 that high side pressure is exerted on the liquid line at the inlet of the valve and low side pressure exists at the outlet of the valve.

For a refrigerant control to operate properly, the control must allow just the right amount of refrigerant flow to keep the evaporator fully active (the evaporator is fully active when the last drop of liquid refrigerant vaporizes at the outlet of the evaporator).

1-2

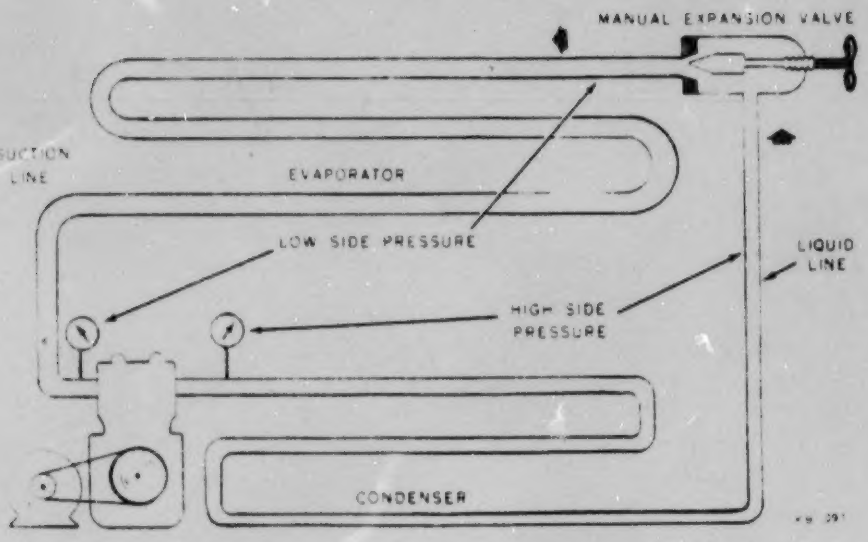

MANUAL EXPANSION VALVE
SUCTION LINE
EVAPORATOR
LOW SIDE PRESSURE
LIQUID LINE
HIGH SIDE PRESSURE
CONDENSER

Figure 1. Manual Expansion Valve in Refrigeration System

Figure 2 illustrates a fully active evaporator. Note that the liquid refrigerant extends from point A (inlet of evaporator) to point C (outlet of evaporator).

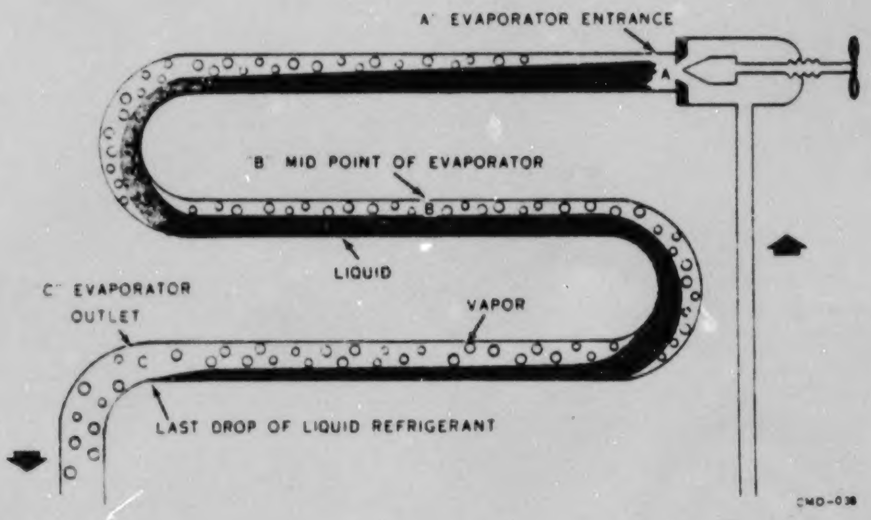

"A" EVAPORATOR ENTRANCE
A
"B" MID POINT OF EVAPORATOR
B
LIQUID
"C" EVAPORATOR OUTLET
VAPOR
C
LAST DROP OF LIQUID REFRIGERANT
CMD-038

Figure 2. Fully Active Evaporator

The manual expansion valve should be opened enough to provide the evaporator with liquid refrigerant from A to C. If the valve is opened more, liquid refrigerant will flow down the suction line to the compressor. This could seriously damage the compressor.

If the valve is not opened enough, the last drop of refrigerant will vaporize at a point in the evaporator away from C. This point is called "V" (point of complete vaporization). See Figure 3.

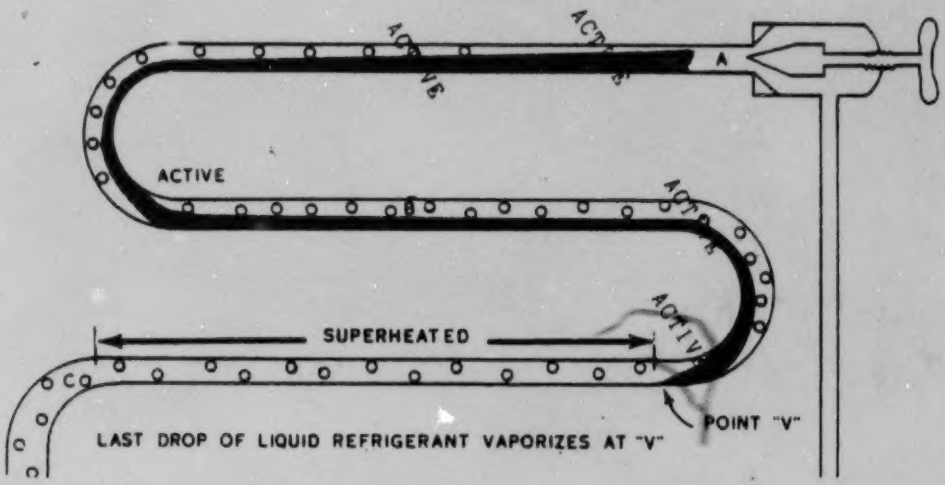


Figure 3. "V" Point of Complete Vaporization

In this case some evaporator efficiency is lost. The evaporator in Figure 3 is not totally efficient. The active part of the evaporator has been reduced, extending only from Point A to V.

The active part of the evaporator absorbs the greatest amount of heat. This portion from V to C contains superheated vapor and has little refrigeration effect, because a few BTUs of heat raises the temperature of a vapor rapidly (vapor only absorbs sensible heat).

In Figure 4, the temperature from A to V is the same. This temperature depends on the temperature-pressure (T-P) relationship of the refrigerant. Using R-12 with a suction pressure of 21 PSI, the temperature from A to V is 20° F.

FLASH GAS. As the hot, high-pressure liquid refrigerant passes through the expansion valve, a small portion of it flashes to a gas (vapor); at that instant the refrigerant becomes a low pressure, low-temperature refrigerant. As the liquid changes to a gas, more space is required. This is called expansion, and because of this, expansion valves are so named.

SUPERHEAT. As the gas leaves point V (see Figure 4), going to the compressor, it continues to absorb heat. In comparison to the active part of the evaporator, the amount of heat is very small and a few degrees of sensible heat causes a great increase in temperature.

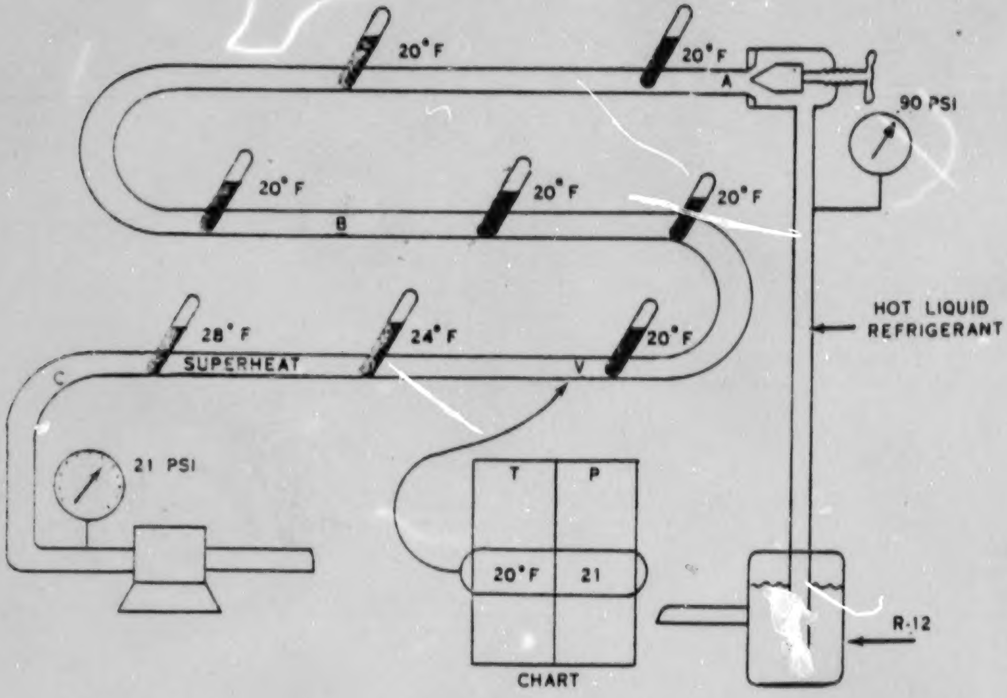


Figure 4. Temperature-Pressure (T-P)

The heat absorbed from point V to C is called superheat. It raises the temperature of the vapor above the saturation point. The PT chart is of no value in this superheated area. The chart is only accurate where liquid refrigerant is in contact with refrigerant vapor.

INCREASE IN HIGH PRESSURE. Assume the valve in Figure 4 is open and point V is in the position shown. If the high side pressure increases, more refrigerant will be forced through the valve. High side pressure, caused by heat loads and air temperature surrounding the condenser, can change from 90 PSI to 110 PSI between midnight and noon. This increase in high side pressure will increase the flow of refrigerant and point V will move to the left.

A decrease in high side pressure will have the opposite effect. Point V is moving to point B, causing the evaporator to be only 50% active. This is referred to as a "starved evaporator."

CHANGE IN HEAT LOAD. In Figure 5, the point of complete vaporization is V_1. When heat is added, the refrigerant in the evaporator boils faster. Point V_1 then moves up the evaporator to V_2. The evaporator is now starved.

A decrease in heat load will have the opposite effect. With less heat, the refrigerant does not boil as fast and point V_1 moves to V_3, flooding the evaporator.

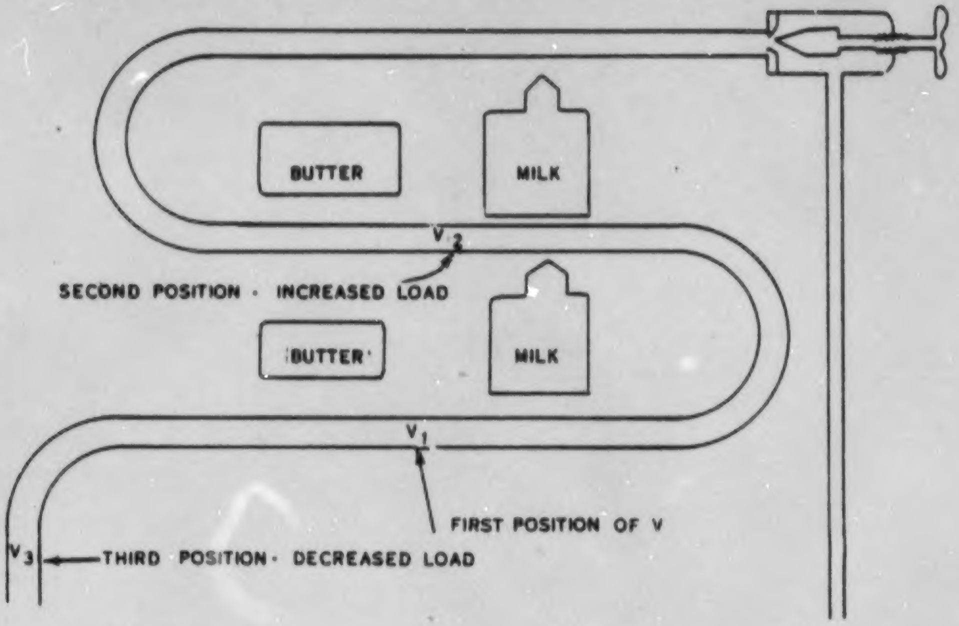

BUTTER
MILK
V2
SECOND POSITION - INCREASED LOAD
BUTTER
MILK
V1
FIRST POSITION OF V
V3
THIRD POSITION - DECREASED LOAD

Figure 5. Heat Load Changes with Manual Expansion Valve

Under ideal conditions, with no change in head pressure or heat load, the manual expansion valve does a very good job. Otherwise, the valve requires constant adjustment. Most of these valves have been replaced with some type of automatic valve.

CAPILLARY TUBE

The capillary tube is located between the condenser and evaporator (see Figure 6), and is one of the most widely used refrigerant controls, being used on practically all small applications such as domestic refrigerators, home freezers, room air conditioning, drinking fountains, and some central air conditioning systems.

Construction

The capillary tube is the simplest of all refrigerant controls, consisting of a small diameter length of seamless copper tubing. The diameter and length depend upon the refrigerant, capacity, and application.

Operation

When a liquid is forced through a pipe or small tube, there is always a resistance to flow. Decrease the diameter or increase the length, and the flow is reduced.

The capillary tube is designed to create enough resistance so that the pressure drop will allow the liquid refrigerant to begin to vaporize. This will occur near the inlet of the evaporator, where its temperature is cooled to the evaporator temperature and pressure.

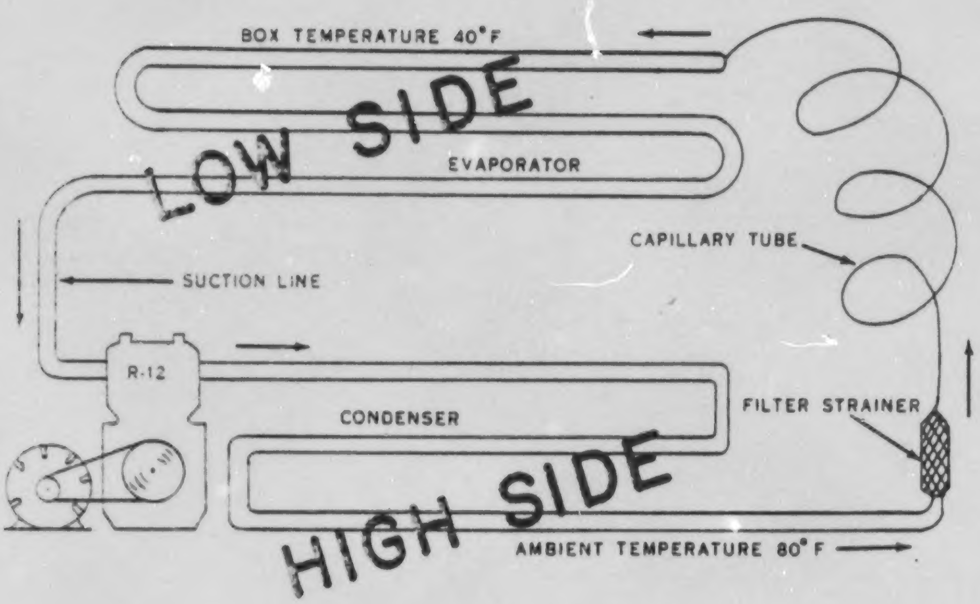

BOX TEMPERATURE 40°F
LOW SIDE
EVAPORATOR
CAPILLARY TUBE
SUCTION LINE
R-12
CONDENSER
FILTER STRAINER
HIGH SIDE
AMBIENT TEMPERATURE 80°F

Figure 6. Capillary Tube in Refrigeration System

The capillary tube equalizes during the off cycle minimizing the starting load on the compressor. Under the low load condition fewer starting devices and less current will be required for the compressor motor.

With the capillary tube the refrigerant charge is critical. Only a limited amount of refrigerant can be placed in the system. If too much refrigerant is in the system, the evaporator pressure will be above normal and the suction line will frost to the compressor. If there is not enough refrigerant, the evaporator will be starved.

The tube is easily clogged or bent. A filter strainer should be installed at the inlet of the capillary tube to prevent dirt and foreign matter clogging the tube.

AUTOMATIC EXPANSION VALVE

This valve was developed to control the flow of liquid refrigerant to the evaporator automatically and does so by maintaining a constant evaporator pressure.

The automatic expansion valve is essentially a pressure-regulating valve (sometimes called a constant pressure valve). This valve is designed to maintain a constant pressure in the evaporator, regardless of changes in heat loads or high side pressure.

Construction Features (See Figure 7)

The automatic expansion valve consists of a closing spring P_3 which pushes upward to close the valve; a needle and needle seat; drive pins which push on the needle carrier to open the valve; a diaphragm; opening spring P_1; an adjusting screw for adjusting the valve; and a vent hole to allow atmospheric pressure P_4 to press downward on the diaphragm.

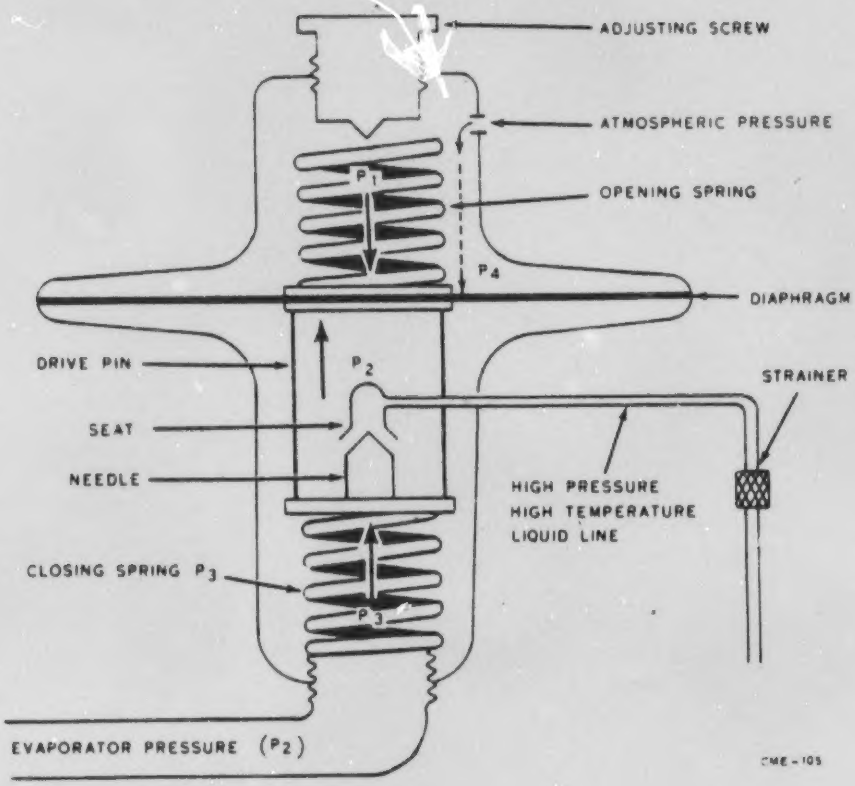

ADJUSTING SCREW
ATMOSPHERIC PRESSURE
OPENING SPRING
P1
P4
DIAPHRAGM
DRIVE PIN
P2
STRAINER
SEAT
NEEDLE
HIGH PRESSURE
HIGH TEMPERATURE
LIQUID LINE
CLOSING SPRING P3
P3
EVAPORATOR PRESSURE (P2)
CME-105

Figure 7. Automatic Expansion Valve

In modern automatic expansion valves, the area above the diaphragm is enclosed with relatively dry air or nitrogen gas. This is done to keep out moist air which might form ice and prevent the spring from opening. It also acts as a cushion and affects the diaphragm in the same way as atmospheric pressure.

Principle of Operation

High-pressure, high-temperature liquid refrigerant from the liquid line changes to a low-pressure, low-temperature liquid at the valve seat (see Figure 7).

Atmospheric pressure P_4 pushes downward to open the valve. Closing spring pressure P_3 pushes upward to close the valve (see Figure 8). These pressures, being equal and opposite, cancel each other and need not be considered. Therefore, the only pressures to consider are opening spring pressure P_1 and evaporator pressure P_2 which close the valve (see Figure 9).

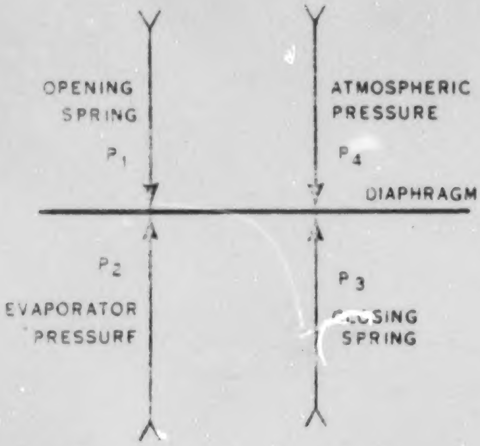


Figure 8. Pressure on Automatic Expansion Valve Diaphragm

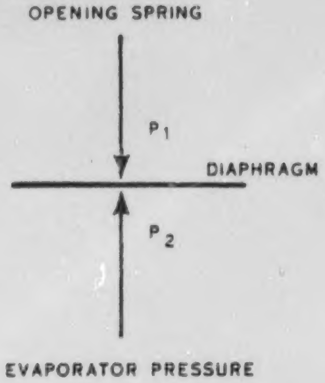


Figure 9. Operating Pressure on Automatic Expansion Valve

Evaporator pressure is varied by changing the pressure on the opening spring. This is accomplished by the adjusting screw. Turning the screw clockwise increases the evaporator pressure. Counterclockwise will decrease evaporator pressure.

During normal operation, the valve is approximately 3/4 open. A slight movement of the needle is necessary. This movement regulates refrigerant flow to keep evaporator pressure almost constant.

OFF CYCLE. When the compressor stops, the valve remains open for a moment. During this time the evaporator pressure P_2 overcomes opening spring pressure P_1 closing the valve.

As the evaporator warms up during the OFF cycle, its pressure rises in accordance with the P.T. chart and may be several PSI above normal operating pressure. The higher the pressure is, the tighter the valve closes.

ON CYCLE. When the compressor starts, the valve does not open immediately. This is an important advantage of the automatic expansion valve. The compressor motor is not overloaded on start-up. This is because the valve will not open until the compressor reduces evaporator pressure to the pressure setting of the valve.

As the compressor reduces evaporator pressure, P_2 becomes less than opening spring pressure P_1 (see Figure 10). This action opens the valve. The valve opens to such a position when P_1 and P_2 are in balance.

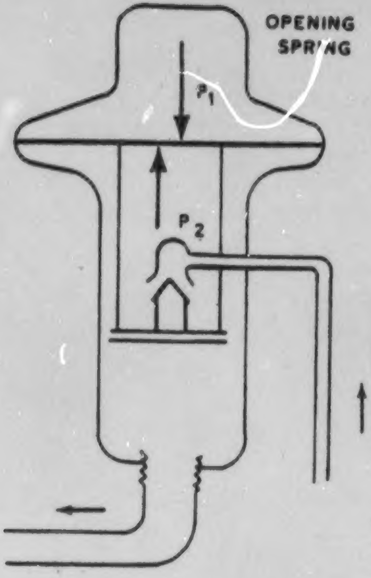


Figure 10. Automatic Expansion Valve when Compressor Starts

INCREASE IN HIGH SIDE PRESSURE. When condensing temperature increases, the high side pressure also increases. The increase in pressure will force more refrigerant through the valve. This causes an increase in evaporator pressure P_2. This unbalances the valve, causing it to close slightly reducing refrigerant flow and evaporator pressure, but P_2 will return to the valve setting.

The automatic expansion valve maintains a fairly constant evaporator pressure and should not fluctuate more than 1/4 PSI during operation.

INCREASE IN HEAT LOAD. Consider a system containing R-12, evaporator pressure P_2 at 21 PSI, and evaporator temperature at 20° F.

Adding a heat load to the system causes the refrigerant to vaporize faster than normal. This causes a rise in evaporator pressure and point V moves to the right (see Figure 11), and this rise in evaporator pressure tends to close the valve allowing less refrigerant to enter the evaporator; therefore, the evaporator is less active.

DECREASE IN HEAT LOAD. A decrease in heat would have an opposite effect. Causing the evaporator pressure to decrease tends to open the valve more. Point V would move to the left, flooding the evaporator. Under this condition, liquid refrigerant could enter the compressor.

This is the main disadvantage of the automatic expansion valve. It starves the evaporator when the heat load is increased and floods the evaporator when the load is decreased.

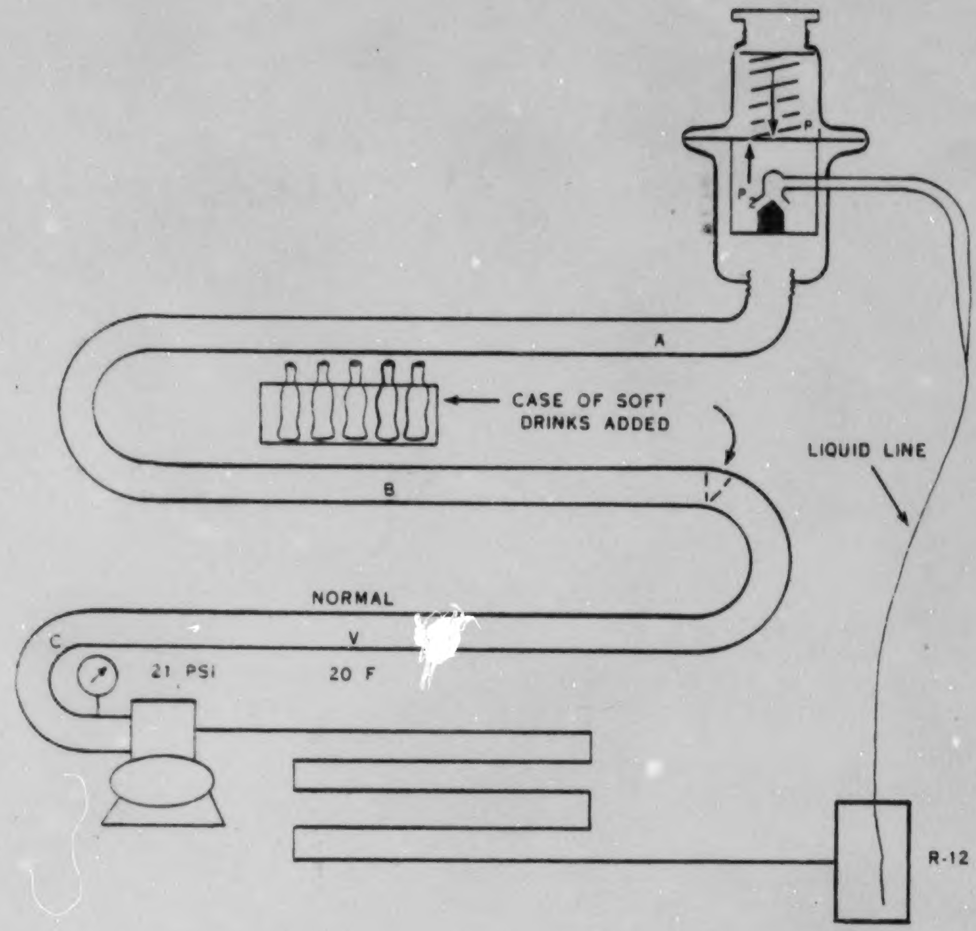

P
P
A
CASE OF SOFT DRINKS ADDED
LIQUID LINE
B
NORMAL
C
V
21 PSI
20 F
R-12

Figure 11. Automatic Expansion Value during Load Change

Adjustment

The automatic expansion valve is adjusted by turning the adjusting stem clockwise to increase evaporator pressure and counterclockwise to decrease the pressure.

This should be accomplished while observing the low side pressure with the manifold gage assembly. Leaving time after each 1/4 turn adjustment for the valve to balance, adjust until a pressure corresponding to the lowest evaporator temperature required during the entire running cycle is attained.

THERMOSTATIC EXPANSION VALVE (INTERNALLY EQUALIZED)

The thermostatic expansion valve is a further development and improvement of the automatic expansion valve, and was introduced to the refrigeration industry in the late twenties. The purpose of this valve is to regulate the flow of refrigerant entering the evaporator, maintaining a fully active evaporator regardless of the heat load and pressure changes. The thermostatic expansion valve does so by maintaining a constant degree of superheat.

NOTE: Superheat is heat added to gas or vapor above its saturated temperature.

Construction Features of the Thermostatic Expansion Valve

The thermostatic expansion valve consists of the following parts (see Figure 12).

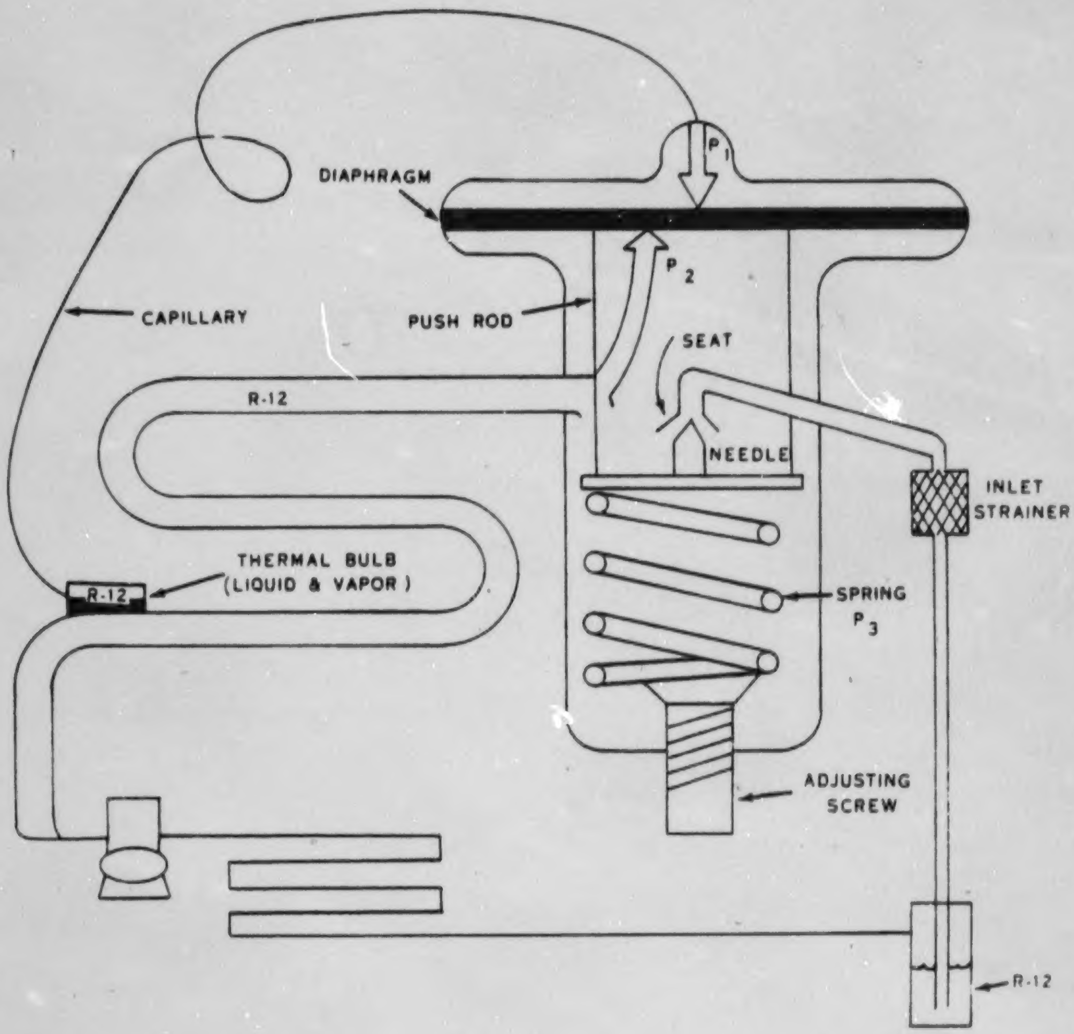

P_1
DIAPHRAGM
P_2
CAPILLARY
PUSH ROD
SEAT
R-12
NEEDLE
INLET STRAINER
THERMAL BULB (LIQUID & VAPOR)
R-12
SPRING
P_3
ADJUSTING SCREW
R-12

Figure 12. Thermostatic Expansion Valve

1. Thermal bulb (power element)
2. Capillary
3. Diaphragm
4. Push rods
5. Valve seat
6. Valve needle
7. Spring
8. Adjusting screw

The thermal bulb contains a charge of refrigerant. Pressure development by the charge is transmitted through the capillary to the diaphragm. The charge in the bulb depends on the application.

Thermal bulb charges are classified in four main groups. They are:

1. Gas-charged
2. Liquid-charged
3. Cross-charged
4. Special charged

NOTE: See bulb charges on page 17.

For simplicity, the gas-charged valve will be discussed, which has the power element and system, each containing R-12.

Referring to Figures 8 and 13, observe the similarity of thermostatic and automatic expansion valves. Note that opening spring P_1 has been replaced by bulb pressure P_1. Evaporator pressure P_2 is the same in both valves. Note that both have springs to close the valve. In the automatic expansion valve, since closing spring pressure and atmospheric pressure are the same, they are not considered. In the thermostatic expansion valve, this closing spring called the superheat spring aids evaporator pressure to close the valve.

Operating Pressure of the Automatic and Thermostatic Expansion Valve

The operating pressures of the automatic and thermostatic expansion valves are compared in Figure 13. Note that both valves have P_1 and P_2. The thermostatic valve has an additional pressure P_3 which helps close the valve. In the automatic expansion valve, P_1 is equal to P_2. The two pressures must be equal to balance the value. In the thermostatic expansion valve, it is: $P_1 = P_2 + P_3$, meaning that the evaporator pressure plus superheat spring pressure is equal to bulb pressure when the valve is in balance.

Operation of the Thermostatic Expansion Valve

In the introduction, you noted that the thermostatic expansion valve maintains a fully active evaporator, regardless of the heat load and pressure changes. In reality this is not quite true. A small portion of the evaporator is used for superheating the vapor because the change in superheat controls the valve.

To understand the operation of the thermostatic expansion valve, refer to Figure 14, Normal Operating System. Both the system and valve will contain R-12 for this exercise. Vary the heat load and observe superheat and pressures P_1, P_2, and P_3.

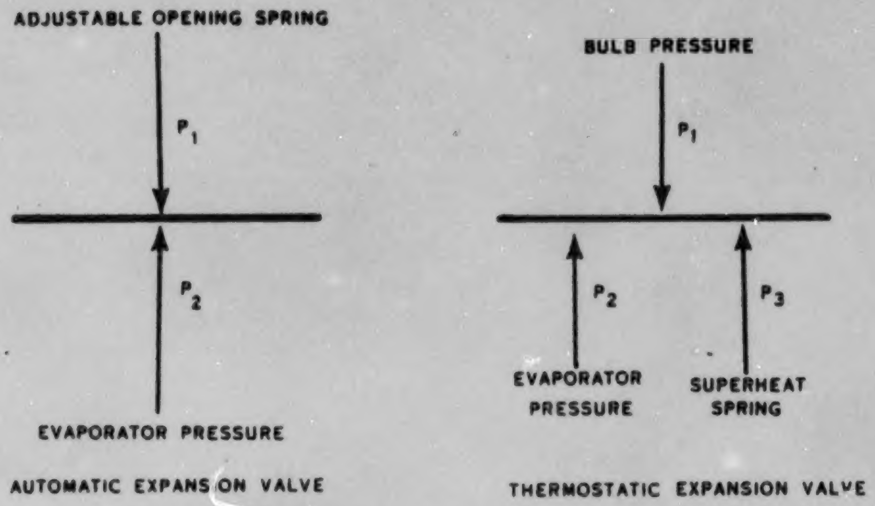

ADJUSTABLE OPENING SPRING
P1
P2
EVAPORATOR PRESSURE
AUTOMATIC EXPANSION VALVE
BULB PRESSURE
P1
P2
P3
EVAPORATOR PRESSURE
SUPERHEAT SPRING
THERMOSTATIC EXPANSION VALVE

Figure 13. Operating Pressures of Automatic and Thermostatic Expansion Valves

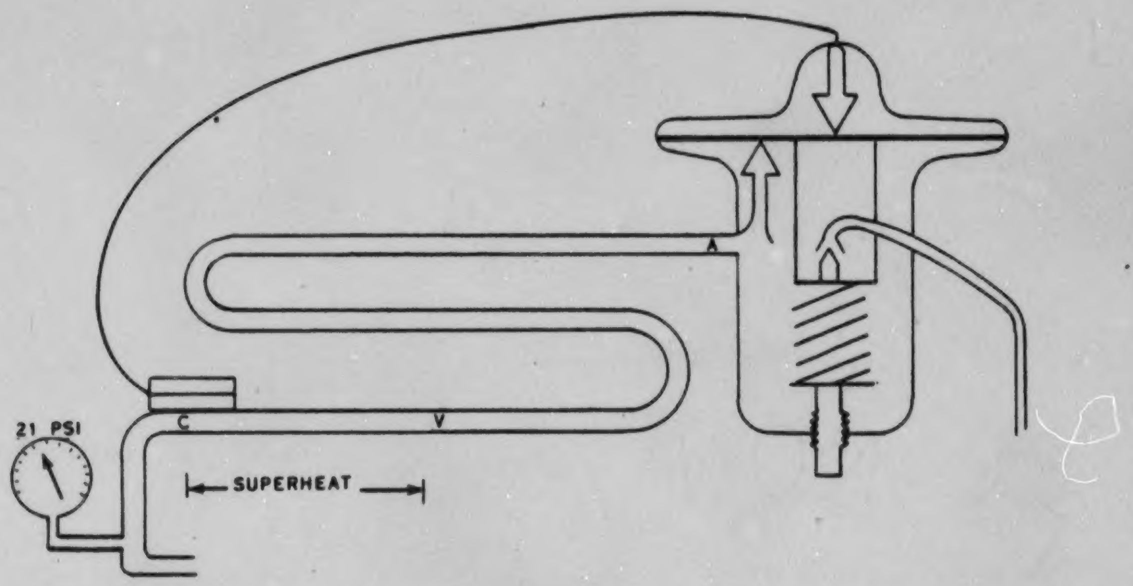

21 PSI
A
C
V
SUPERHEAT

Figure 14. Normal Operating System with R-12 Refrigerant

Point V is the point of complete vaporization. The temperature of the liquid and vapor from V to A is the same. Knowing where point V is located is not too important, but the temperature at point V is. The temperature at point V can be known by converting suction pressure to temperature. In Figure 14, suction pressure is 21 PSI. The temperature from A to V is 20° F.

SUPERHEAT. To find superheat, attach the bulb of a superheat thermometer at point C 30° F. (see Figure 15). Convert suction pressure to temperature: 21 PSI = 20° F. This is the temperature at point V. Subtract the temperature at point V from the temperature at point C: 30° F - 20° F = 10° F superheat.

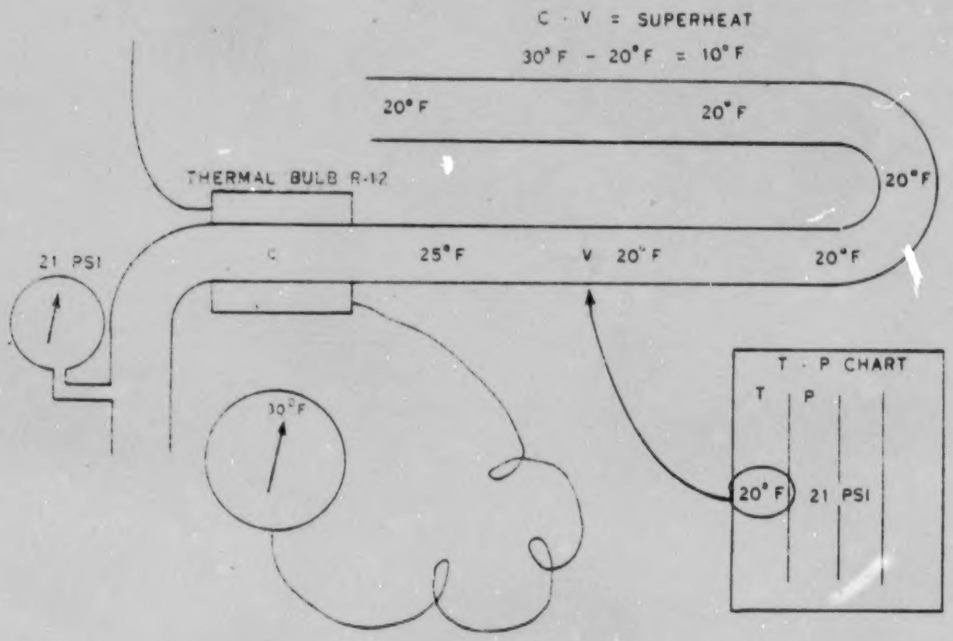


Figure 15. Finding Superheat

FINDING PRESSURE P_1. In order to find P_1, the temperature of the thermal bulb must be converted to pressure. Referring to Figure 16, the temperature at point C is 30°. The thermal bulb temperature is also 30° and 30° = 29 PSI, P_1 = 29 PSI.

FINDING PRESSURE P_2. Pressure P_2 is 21 PSI (see Figure 16).

FINDING PRESSURE P_3. If $P_1 = P_2 + P_3$ and P_1 = 29 PSI, P_3 = 8 PSI.

INCREASE IN HEAT LOAD. Referring to Figure 14, normal refrigeration system pressure P_1 is in balance with $P_2 + P_3$. Normal superheat is 10° F.

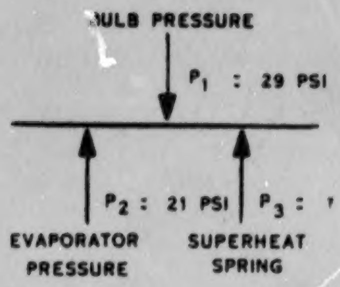

ULB PRESSURE
P1 : 29 PSI
P2 : 21 PSI
P3 :
EVAPORATOR PRESSURE
SUPERHEAT SPRING

Figure 16. $P_1 = P_2 + P_3$

When the heat load increases the refrigerant boils faster; point V (Figure 17) moves towards the expansion valve. Assuming the suction pressure remains at 21 PSI and the superheat spring at 8 PSI, the temperature at point C will increase perhaps to 32° F. Superheat is now 32° F - 20° F = 12° F. Bulb pressure P_1, according to the temperature relationship chart for 32° F, has increased from 29 PSI to 30 PSI. P_1 is now greater than $P_2 + P_3$ (29 PSI). The valve opens, allowing refrigerant flow to match the load. Pressures balance at the new flow rate and superheat returns to normal.

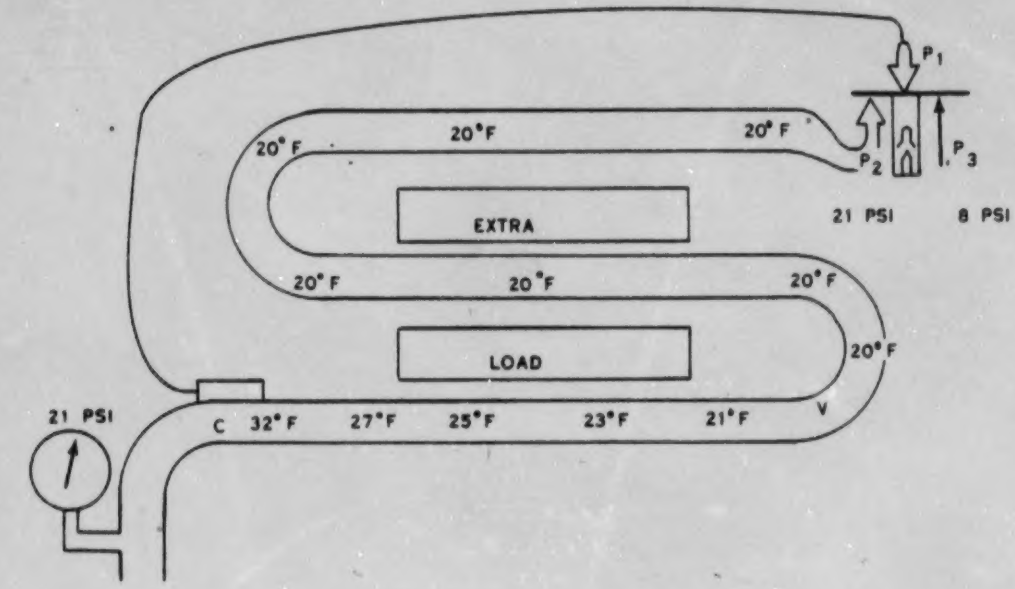

P1
20° F
20°F
20° F
P2
P3
21 PSI
8 PSI
EXTRA
20° F
20°F
20°F
20°F
LOAD
21 PSI
C
32°F
27°F
25°F
23°F
21°F
V

Figure 17. Increase Heat Load

DECREASE IN HEAT LOAD. As the heat load decreases, point V moves closer to point C. Superheat becomes less than 10° F. and the temperature at point C becomes less than 30° F. In this case, P_1 becomes less than $P_2 + P_3$; the valve closes slightly, reducing refrigerant flow. Pressures balance at the new flow rate and superheat returns to normal.

FROST AND LIQUID REFRIGERANT. When frost forms on the suction line, it only indicates the temperature at the end of the frost line is 32° F. This can be caused by low temperature vapor or liquid refrigerant. If there is one or more degrees of superheat, the frost is caused by low-temperature vapor.

CHECKING SUPERHEAT. There are three methods used to check superheat. The first is the ice bath test. This method is fairly accurate, providing the manufacturer's recommendations are followed. The second method is using two superheat thermometers. One is attached at the inlet of the evaporator, and the other, at the bulb of the thermostatic expansion valve. Subtract the temperature at the inlet of the evaporator from the temperature at the bulb. The third and most accurate method is one superheat thermometer at the bulb of the expansion valve and evaporator pressure (see Figure 15). Convert evaporator pressure to temperature, and subtract from temperature at bulb. The difference between these two is the amount of superheat.

NOTE: The bulb of the superheat thermometer must be well-insulated.

Thermal Bulb Location

The thermal bulb should be clamped to a horizontal suction line near the evaporator outlet. The suction line should be cleaned thoroughly before clamping the remote bulb in place. On suction lines under 7/8" OD, the remote bulb should be installed on top of the line and on 7/8" OD up to 2-1/8" OD. The bulb should be installed at the position of 4 or 8 o'clock (see Figure 18). On lines 2-1/8" and larger, the bulb should be installed inside the suction line.

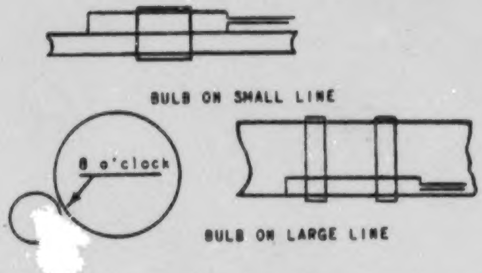


Figure 18. External Bulb on Suction Line

The thermal bulb must never be placed where the suction line is trapped (see Figure 19). Any collection of liquid refrigerant at the point of thermal bulb location will cause irregular operation of the expansion valve. Large fluctuations in pressure and superheat of the suction gas are usually the result of trapped liquid at the remote bulb location. Even on properly designed suction lines, it is sometimes necessary to move the bulb a few inches either way from the original location to obtain the best valve action. Always locate the thermal bulb on the evaporator side of a heat exchanger.

When locating the remote bulb outside the refrigerated space, both the bulb and the suction line must be well-insulated from the surrounding ambient temperature. The insulation must extend at least one (1) foot or more beyond the bulb location on both sides of the bulb. When the thermal bulb is located inside the refrigerated space, the temperature difference between the evaporator and space is not usually large enough to adversely affect expansion valve operation.

"Hunting" of the expansion valve can be defined as the alternate overfeeding and starving of the evaporator. It is recognized by extreme cycle changes in both the superheat and the suction pressure.

The following schematic drawing illustrates one of the more common incorrect remote bulb applications that can cause valve "hunting" and "flood back." Drawings of recommended corrections to the piping and remote bulb location to avoid these conditions are included. In Figure 19, liquid can trap in the suction line at the evaporator outlet, causing the loss of operating superheat and results in irregular valve operation due to the alternate drying and filling of the trap. Figure 20 shows the piping corrected and the trap removed. This allows free drainage away from the remote bulb location.

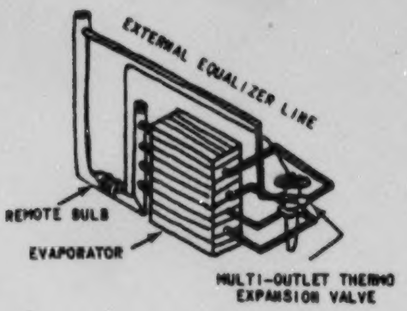

EXTERNAL EQUALIZER LINE
REMOTE BULB
EVAPORATOR
MULTI-OUTLET THERMO EXPANSION VALVE

Figure 19. Remote Bulb Location Shown Trapped

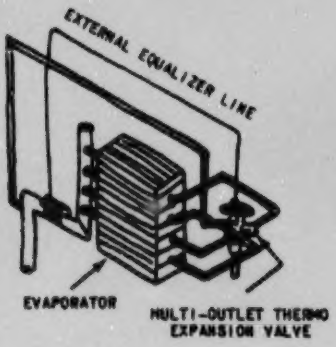

EXTERNAL EQUALIZER LINE
EVAPORATOR
MULTI-OUTLET THERMO EXPANSION VALVE

Figure 20. Remote Bulb Location Shown Free Draining

Figure 21 illustrates the proper remote bulb location to avoid trapped oil or liquid from affecting the expansion valve's operation when the suction line must rise at the evaporator's outlet.

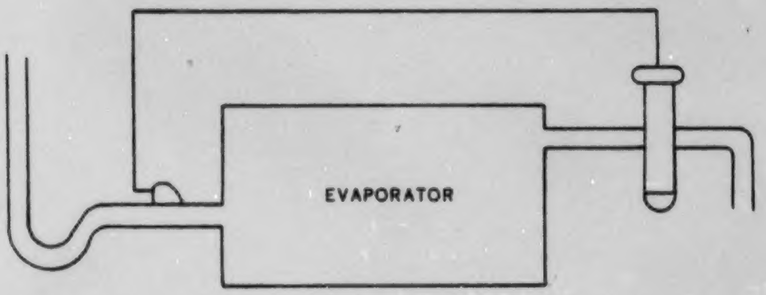

EVAPORATOR

Figure 21. Recommended Remote Bulb Location and Schematic Piping for Rising Suction Line

Thermal Bulb Charge

Thermostatic expansion valves require a different type of refrigerant charge in the thermal bulb for each temperature range (see Figure 22). The dividing line between the different charges is not a clear-cut point. A gas charge valve can be used in applications with a temperature as low as 26° F without too much loss in efficiency. Also a cross-charged valve can be used where the temperature reaches 35 to 37° F.

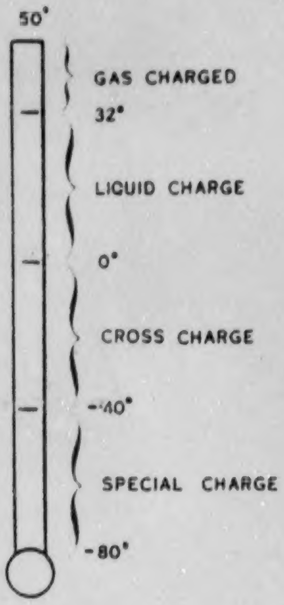


Figure 22. Temperature Ranges of Valves

The thermal bulb or (power element) contains a charge of refrigerant. Pressure developed by the bulb is transmitted through the capillary to the diaphragm. The charge in the bulb depends on the application and is classified under four groups.

GAS-CHARGED VALVE. The bulb contains the same type of refrigerant as used in the system. The amount of refrigerant is limited so that at a predetermined temperature all refrigerant has vaporized. This limits the amount of pressure that can be exerted by the bulb and is called M.O.P. (maximum operating pressure). Any time the evaporator pressure becomes greater than the M.O.P., the valve closes and remains closed until the evaporator pressure is reduced below the M.O.P.

ADVANTAGES.

1. Prevents flooding the evaporator during the OFF cycle.
2. Allows rapid pull-down.
3. Prevents overloading the compressor motor.

DISADVANTAGES.

1. The gas-charged valve cannot be used on low-temperature applications.
2. If the body of the valve becomes colder than the bulb, the charge will condense in the body of the valve, and control by the bulb will be lost.

CROSS-CHARGED VALVES. Cross-charged valves use a different fluid in the power element than the refrigerant in the system. The cross-charged valve is especially useful in low-temperature applications. The cross-charged valve creates a high initial superheat which tends to prevent flood-back and motor overload during initial pull-down. At high evaporator temperatures, the valve maintains a very high superheat; as the evaporator temperature lowers, the superheat gradually returns to normal. When the compressor stops, the valve closes quickly to prevent flooding the evaporator.

SPECIAL-CHARGED VALVES. Ultralow-temperature refrigeration (-40°F and less) uses a special-charged valve. Each application requires its own special engineered valve. Before changing type or size of these valves, the valve manufacturer should be consulted.

LIQUID-CHARGED VALVES. Liquid-charged valves contain the same refrigerant as the system. This type of valve operates on the principle of expansion or contraction of a liquid as it changes temperature.

ADVANTAGES. The valve will control refrigerant flow even if the valve body is colder than the thermal bulb.

DISADVANTAGES.

1. During the initial pull-down when the compressor starts, the evaporator temperature is immediately reduced. Since the thermal bulb is not cooled as fast as the evaporator, the pressure difference across the diaphragm tends to:
   a. Completely open the valve with a possibility of flood-back.
   b. Impose a maximum load on the motor during pull-down.
   c. Delay suction pressure pull-down.
2. During the OFF cycle, the bulb may warm up enough to open the valve. This will flood the evaporator and cause flood-back on start-up.

Liquid-charged valves must contain some type of pressure-limiting device. The pressure-limiting device causes liquid-charged valves to cost more than gas- or cross-charged valves.

If the valve body must be located in an area that is colder than the thermal bulb, a liquid-charged valve must be used.

Pressure Limiters. Liquid-charged valves must contain a pressure-limiting device. This can be accomplished by introducing a gas-charged pressure cartridge or collapsible link between the diaphragm and the push rods that open the needle valve (see Figure 23).

As long as the evaporator pressure is below the pressure charge of the cartridge, the cartridge acts as a solid piece, transmitting the power element pressure to the push rods. When the pressure in the evaporator exceeds the cartridge pressure, the cartridge collapses, allowing the spring to close the valve. The valve will remain closed until the evaporator pressure has been reduced below that in the cartridge.

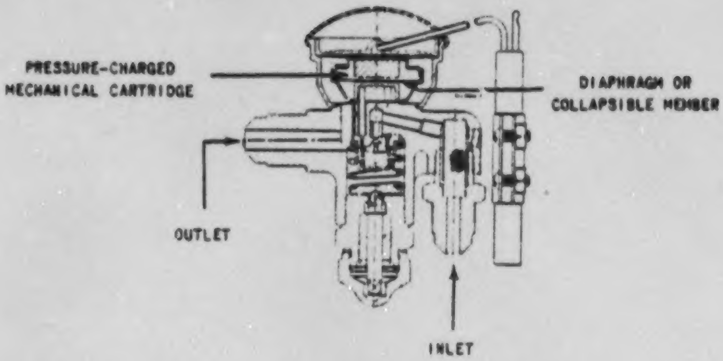

PRESSURE-CHARGED MECHANICAL CARTRIDGE
DIAPHRAGM OR COLLAPSIBLE MEMBER
OUTLET
INLET

Figure 23. Pressure-Limiting Device

Selection of Thermostatic Expansion Valve

1. System capacity or tons
2. Type of refrigerant
3. Evaporator temperature; this will determine the M.O.P. bulb charge and if a pressure limiting device is needed
4. Pressure difference across the valve
5. Valve fittings, both inlet and outlet size

With all the foregoing information the proper size thermostatic expansion valve can be selected from the manufacturer's catalog.

NOTE: It is important to remember that in some cases the thermostatic expansion valve can be repaired.

THERMOSTATIC EXPANSION VALVE (EXTERNALLY EQUALIZED)

On large systems, the pressure drop across the evaporator varies from 1 to 10 pounds with an internally equalized valve; this pressure drop causes a very high degree of superheat, indicating that the evaporator is not fully active.

To compensate for the pressure drop across the evaporator, the thermostatic expansion valve externally equalized was developed.

The equalizer line should be installed as near the bulb as possible toward the compressor (see Figure 24).

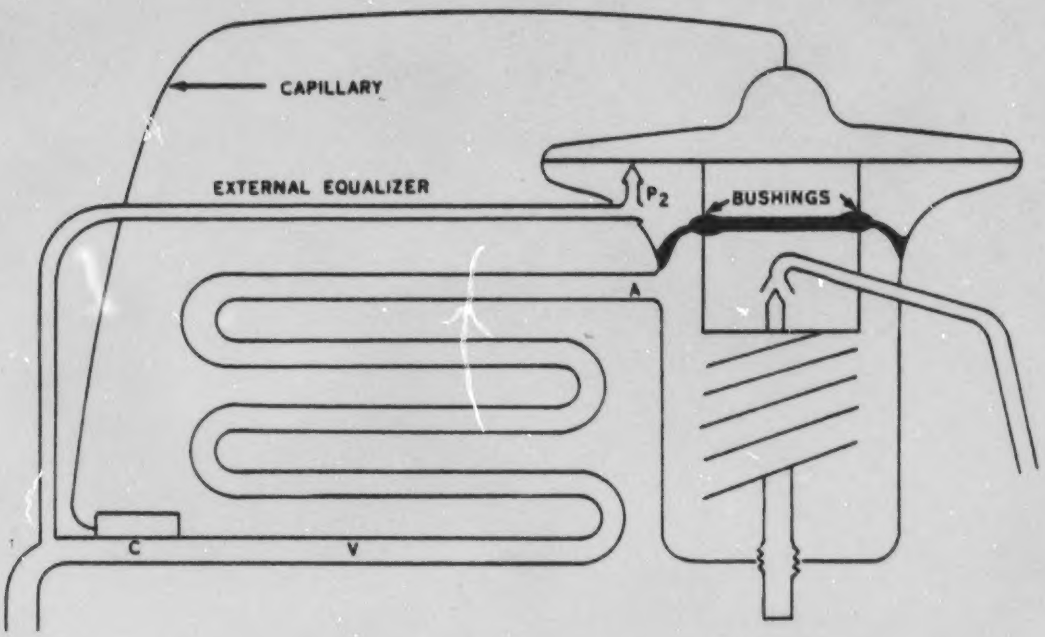


Figure 24. Thermostatic Expansion Valve (Externally Equalized)

The equalizer line brings the evaporator outlet pressure under the diaphragm. Note that the valve is feeding the evaporator at inlet A, but is controlled by evaporator outlet pressure (equalizer pressure) at C.

Anytime the pressure drop across the evaporator exceeds the limits shown in Figure 25, an expansion valve with an external equalizer should be used.

Air Conditioning	(32 to 50° F)	2-1/2 PSI
Commercial Range	(32 to 0° F)	1-1/2 PSI
Low-Temperature Range	(0 to -40° F)	1/2 PSI

Figure 25. Pressure Drop

Superheat Check with External Equalized Valve

Superheat is checked in the same way on both valves (see Figure 15).

Superheat Adjustment

Superheat adjustment is made by the manufacturer and seldom requires changing. However, when it is found necessary to adjust the superheat the manufacturer's recommendations should be followed.

NOTE: Turning the adjusting stem clockwise increases superheat.
Counterclockwise decreases superheat.

Troubleshooting

Thermostatic expansion valves are well constructed and seldom cause trouble. However system malfunctions can easily be found by troubleshooting the expansion valve using the two-system method, suction pressure and superheat. Superheat should be 10 degrees and suction pressure can be calculated by subtracting design evaporator temperature difference from the space temperature and converting to pressure with the P-T chart.

LOW SUCTION PRESSURE AND HIGH SUPERHEAT (Starved evaporator)

1. Liquid line vapor
    a. Clogged drier or strainer
    b. Long liquid line
    c. Low charge
    d. Vertical lift
2. Moisture freezing at expansion valve
3. Lost bulb charge
4. Needle stuck shut
5. Undersized valve or orifice
6. Evaporator pressure drop - no external equalizer
7. Low pressure drop across the valve
8. High superheat adjustment

LOW SUCTION PRESSURE AND LOW SUPERHEAT (Low flow, evaporator flooded)

1. Low load
2. Poor air flow across evaporator
    a. Dirty evaporator or filter
    b. Evaporator fan malfunction
    c. Coil icing
3. Evaporator oil logged

HIGH SUCTION PRESSURE AND LOW SUPERHEAT (Flooded evaporator)

1. Bulb installation
    a. Poor contact
    b. Warm location
2. TEV seat leaking
3. Moisture freezing holding valve open
4. Bad compressor (low capacity)
5. Oversized valve or orifice
6. Wrong bulb charge
7. Restricted external equalizer
8. Low superheat adjustment

SUMMARY

All refrigerant control devices control the amount of refrigerant flowing to the evaporator. The method of opening or closing a valve determines the type of control devices. The capillary tube, of course, is an exception because it is a long tube with a fixed opening.

The thermostatic expansion valve is the most efficient refrigerant control ever devised because it will maintain a fully active evaporator under all operating conditions. The thermostatic valve maintains an active evaporator by controlling evaporator superheat.

When troubleshooting a system that is using a thermostatic expansion valve, do not guess. Use two-system method and figure out what is causing the trouble; the chances are nine to one that the expansion valve does not need replacing.

QUESTIONS

1. What is the general purpose of metering devices?
2. Name four refrigerant control devices?
3. What affects the refrigerant flow of the manual expansion valve?
4. What is the advantage of the capillary tube?
5. How is a capillary tube constructed?
6. What is the purpose of an automatic expansion valve, and how is this function accomplished?

7. What is the main disadvantage of the automatic expansion valve?

8. Explain the importance of point V (point of complete vaporization).

9. Define superheat and explain its importance.

10. What is the purpose of the thermostatic expansion valve?

11. How does the thermostatic valve accomplish its purpose?

12. How would you find the temperature of refrigerant at point V?

13. How would you find the temperature at point C?

14. List the methods that are used to determine superheat and explain each.

15. What is the purpose of an external equalizer?

16. What are the operating pressures of the external equalizer?

17. Explain the purpose and operation of pressure limiters.

18. Define and explain M.O.P.

19. What is the two-system method of troubleshooting TEV?

REFERENCES

1. AFM 85-18, Maintenance and Operation of Refrigeration, Air Conditioning, Evaporative Cooling and Mechanical Ventilating Systems

2. Modern Refrigeration and Air Conditioning, Althouse and Turnquist

3. Commercial and Industrial Refrigeration, Nelson

4. Refrigeration, Air Conditioning, and Cold Storage, Gunther

5. Principles of Refrigeration, Dossat

MOTOR CONTROLS

OBJECTIVE

To help you in learning the principles of operation, purpose, and adjustment of motor controls.

INTRODUCTION

At this point in our study of refrigeration systems, we have learned that the system depends on human aid for starting and stopping. This is not satisfactory as it would require constant attention to maintain the temperature of the conditioned space within limits. By placing a switch that opens and closes in response to temperature changes in the power lead to the motor, the system can be made completely automatic.

THERMOSTATIC MOTOR CONTROLS

The purpose of a motor control is to maintain a relatively constant temperature within the refrigerated space. This is accomplished by starting the unit when the temperature rises and by stopping the unit when the temperature falls. Figure 26 illustrates the characteristics of an automatically controlled unit. From this diagram, it can be seen that the temperature within the refrigerated space is not constant. It is continually rising and falling between two predetermined points (30° to 40°).

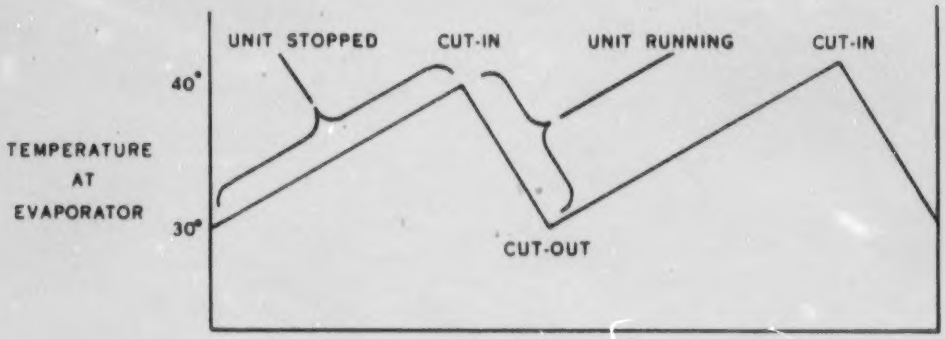


Figure 26. Temperature Fluctuations

A motor control is always connected electrically in series with the motor. Its location is illustrated systematically in Figure 27 and 28. As you can see in this diagram, the contact points of the control (represented by the "T" bar) allow current to flow to the motor when they bridge the gap in the power line and stop the current flow when they open.

The thermostatic motor control (TMC) senses temperature rather than pressure. These motor controls can be used on most types of refrigeration and air-conditioning units. However, they must be used on all units that have automatic expansion valves or capillary tube refrigerant control devices.

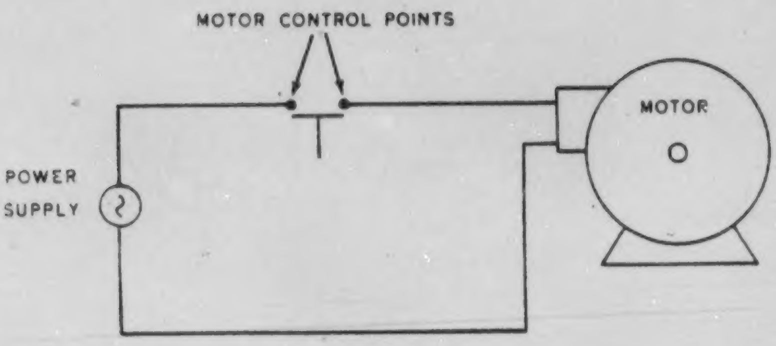

MOTOR CONTROL POINTS
MOTOR
POWER
SUPPLY

Figure 27. Location of Motor Control

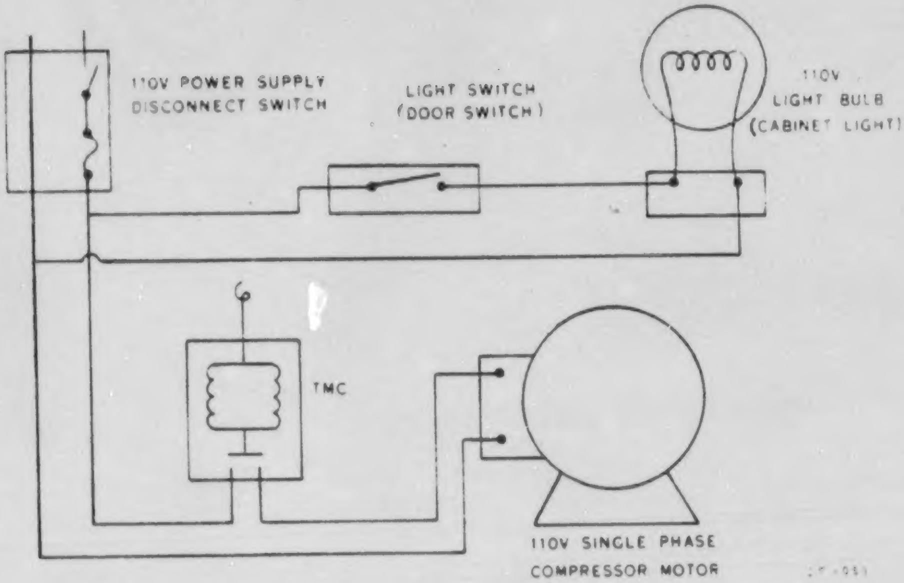

110V POWER SUPPLY
DISCONNECT SWITCH
LIGHT SWITCH
(DOOR SWITCH)
110V
LIGHT BULB
(CABINET LIGHT)
TMC
110V SINGLE PHASE
COMPRESSOR MOTOR

Figure 28. Wiring Diagram of Single-Phase Motor Control

Principle of Operation

The principle of operation of the TMC is a basic physics law which states that matter will expand when heated and contract when cooled. If a container were sealed after being completely filled with water and heat were applied, the pressure built up due to the heating could burst the container. If the temperature is reduced, the pressure exerted on the sides of the container also reduces. This physical law holds true if the container holds a liquid, a gas, or a combination of the two.

The TMC consists of two major parts: a housing, containing the operational lever mechanism, and a power element which is attached to the housing. The power element can be further broken down into three parts: a "feeler" bulb, a capillary tube, and a bellows. The three parts of the power element are connected together and are hollow. Inside this hollow element, there is a refrigerant charge which is either a liquid, a gas, or a combination of both. This charge is completely independent of the charge in the unit itself. The charge is very critical. Any leak, no matter how small, will render the power element inoperative.

The bulb of the power element is located in such a position as to be sensitive to any change in the temperature of the controlled space. For domestic units, this location is on the evaporator so as to control the evaporator temperature. It might also be fastened inside the refrigerated space.

Any rise in temperature will heat the bulb, causing the charge to expand. This expansion will be transmitted through the capillary tube to the bellows. This will cause the bellows to expand. Attached to the bellows and inserted into the housing to rest against one end of the lever system is a short push rod. The pressure of the power element will expand the bellows, pushing the rod against the lever. This level will cause other levers to move and the net result will be a set of electrical contact points closing. Closing of the points will cause the motor to start and the unit will be in operation.

As the temperature at the feeler bulb drops so will the temperature of the bulb itself. This causes a drop in power element pressure and will reduce the push on the lever system. Part of the lever system consists of a spring which counteracts the power element pressure. As the element pressure drops, the spring will pull the points apart and stop the motor.

By turning the adjusting knob clockwise, the spring will become compressed, causing the cut-in temperature to rise. Compressing the spring puts more pressure in opposition to the power element and demands that the element heat up even more to overcome this increased pressure, closing the points. The converse (by turning the knob counterclockwise) will decrease spring tension and lower the cut-in point.

The TMC has a second spring that works in conjunction with the power element instead of against it. This spring is used to set the "cut-out" temperature (on some controls) or the differential (on other type controls).

Motivating Units

For discussion purposes, a bellows was used to explain the operation of the LPMC. However, there are four different types of motivating devices used to open and close the contact points in electrical controls:

1. Bellows

2. Diaphragm

3. Bourdon Tube

4. Bimetallic Element

BELLOWS. The bellows (Figure 29) may be connected directly to the condensing unit by means of tubing, or they may be actuated by the pressure in a temperature bulb. The pressure will cause the bellows to expand or contract. This movement is used to open or close the electrical switch.

DIAPHRAGM. A diaphragm-type power element (Figure 30) is used in some controls. The complete power element consists of a thermal bulb, capillary tube, and diaphragm filled with a liquid or gas. Changes in temperature at the bulb will cause an increase in the volume of the liquid and a subsequent change in the diaphragm. This movement of the diaphragm is used to open or close the electrical switch.

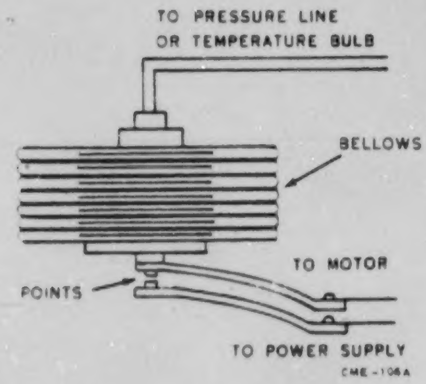


Figure 29. Bellows

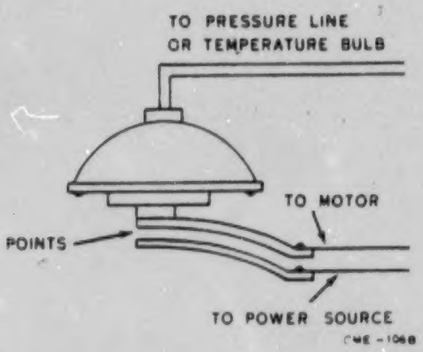


Figure 30. Diaphragm

BOURDON TUBE. A bourdon tube (Figure 31) is used in some pressure controls. The bourdon tube is the same as the one used in pressure and vacuum gages. An increase in pressure will tend to straighten the tube while a decrease in pressure will cause it to curl up. The movement of the tube due to changes in pressure is made to operate a switch.

BIMETALLIC ELEMENT. A bimetallic element (Figure 32) is used in air conditioning thermostats. The elements consist of two dissimilar metals fastened securely together. A change in temperature will cause the strip to bend. This motion is used to open or close the electrical switch. When using this element as a motivating unit for a thermostatic motor control, the entire control must be located inside the refrigerated space (room thermostat).

Application

Two types of bimetallic strip applications (Figure 33) are snap-action and mercury bulb. Snap action switches minimize electrical arcing to prevent excessive burning or pitting of the contact points.

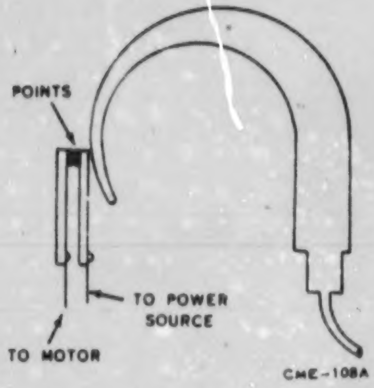
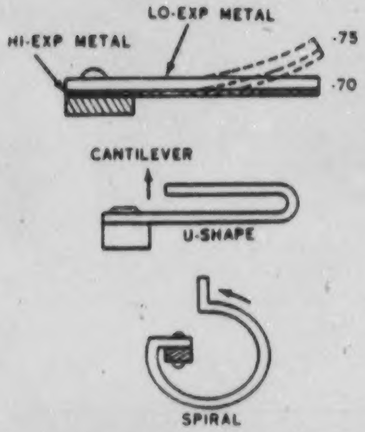

POINTS
TO POWER SOURCE
TO MOTOR
CME-108A

Figure 31. Bourdon Tube

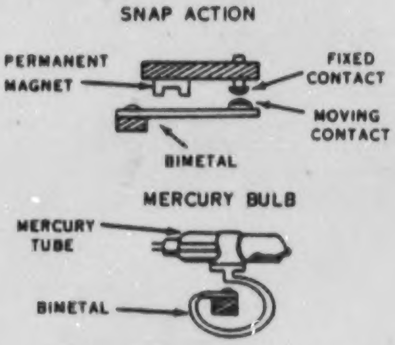

LO-EXP METAL
HI-EXP METAL
.75
.70
CANTILEVER
U-SHAPE
SPIRAL

ARROW INDICATES DIRECTION OF MOTION UPON APPLICATION OF HEAT.

THE ABOVE FIGURE IS AN EXAGGERATED EXAMPLE OF MOVEMENT OF THE UNANCHORED END OF THE BIMETALLIC ROOM THERMOSTAT ON AN INCREASE IN AIR TEMPERATURE SHOWN BY ARROWS

CME-108B

Figure 32. Bimetallic Elements


SNAP ACTION
PERMANENT MAGNET
FIXED CONTACT
MOVING CONTACT
BIMETAL
MERCURY BULB
MERCURY TUBE
BIMETAL

IF A MERCURY SWITCH IS SUBSTITUTED AND ATTACHED TO A SPIRAL BIMETAL IN THE OPERATION OF THE THERMOSTAT, THE ELECTRICAL CIRCUIT WOULD BE COMPLETED INSIDE THE MERCURY TUBE SWITCH BY THE BALL OF MERCURY BETWEEN THE TWO ELECTRODES INSIDE THE TUBE.

CME-108C

Figure 33. Bimetallic Applications

Location of Feeler Bulb

Generally, the feeler bulb will be tightly clamped to the evaporator. The TMC will operate on the evaporator temperature.

The bulb can be located elsewhere if the situation demands it; some bulbs will be located in the cold box rather than on the evaporator. In this case, the TMC will operate on the cold box temperature. On ice-making machines, the feeler bulb should be located in the ice bin. In this application, the TMC will shut the unit off when the ice level reaches the feeler bulb and cools it off. When the ice falls below the bulb, the bulb will warm up and turn the unit on.

If the refrigerated space has forced air circulation, the TMC bulb should be mounted in the return air stream.

Replacement

The control mechanism is so delicately built that it is impractical to repair in the field. If operation is erratic because of power element failure, mechanical (lever) action failure, or contact point failure, the entire control should be replaced.

Checking Thermostatic Motor Controls

Thermostatic motor controls are very delicate instruments. However, if they are not misused, they will give years of trouble-free service. Thermostatic motor controls are subject to several troubles, each of which usually requires replacement of the complete control. Some of the common troubles are:

LOSS OF CHARGE. Occasionally, the power element will lose part or all of its charge. This charge is very small and any loss at all will cause the unit to fail. A kinked or clogged capillary tube will give the same indication as a loss of charge. Usually a power element failure requires replacement of the complete control. However, it is possible to get replacement power elements for some controls. Needless to say, great care must be taken to insure that you have the correct replacement item.

BURNED CONTACTS. Even though there is snap action when the points open and close, they will burn. In such cases, the points will either stick closed or become pitted and never close. In some cases, the points can be filed and the control will operate satisfactorily for a period of time. Filing the points should be considered a temporary repair and the control should be replaced as soon as possible.

WEAR. The parts of a TMC are light and do not move very far, but they do move many, many times each day. One should not become too concerned about wear unless the unit has been in use a long time.

ELECTRICAL. Low and high voltages, high current flow, frayed insulation, bad electrical contacts, and various other electrical malfunctions will cause the TMC to fail. Electrical troubles can often be determined and repaired without having to replace the control.

TINKERITIS. This malfunction is caused by unauthorized personnel attempting to adjust the controls. When this condition is found, readjust the control and instruct the user in the correct function and purpose of the control. Also indicate that adjustment by unauthorized personnel usually results in inefficient operation.

Attempts to tape, seal, or solder the adjustment screws seem to cause more, rather than less, tinkeritis.

LOW-PRESSURE MOTOR CONTROL

When studying the operation of the low-pressure motor control (LPMC), the first question that comes to mind is: How can a pressure-actuated device control temperature? The answer is simple. Remember that the pressure above a liquid determines its boiling point. This characteristic is reliable and definite (refer to a temperature-pressure relationship chart). Refrigerant 12 under a pressure of 37 PSI will boil at 40° F. Going one step further, if we have a system that uses Refrigerant 12 and controls the evaporator pressure at 37 PSI, we can expect a temperature of 40° F. Therefore, we have controlled the temperature by controlling the pressure.

Motivating Units

The motivating units for a pressure motor control are:

1. Bellows (Figure 29)
2. Diaphragm (Figure 30)
3. Bourdon tube (Figure 31)

NOTE: The bimetallic elements, being temperature - sensitive and not pressure actuated, are not used with pressure motor controls.

Adjustment of Low-Pressure Motor Control

There are many variations in the characteristics of individual types of motor controls. Generally, each control is provided with adjustment of one kind or another. This permits the operator to select the operating condition best suited for a particular application. One of the most useful tools in the adjustment of controls is the pressure control setting chart.

If there is no control setting chart for a particular box, the next approach is to use the pressure-temperature relationship chart. In this case, estimate the desired temperatures and convert these temperatures to pressures. Set the control for these pressures. As an example, the desired temperatures are 10° to 25° F, using R-22 as a refrigerant. Referring to the P-T chart, R-22 will produce these temperatures at a pressure of 33 to 49 PSI. Set the control for these pressures and the box should operate at the desired temperatures. (This explanation is for discussion purpose only. In reality, there will be approximately 10° F to 20° F difference between box temperature and evaporator temperature.)

To utilize this method of setting controls, the operator must have enough experience to make good approximations of the desired operating temperature.

The next problem is to determine the adjustments that are to be made on a control in the field. There are two common adjustments of low pressure controls, adjustment of cut-in and cut-out (see Figure 34) and adjustment of cut-in and differential (see Figure 35).

The difference in adjustment of these two types of controls is very minor. However, to make sure that the procedures are well understood, let us solve a problem using both types of controls.

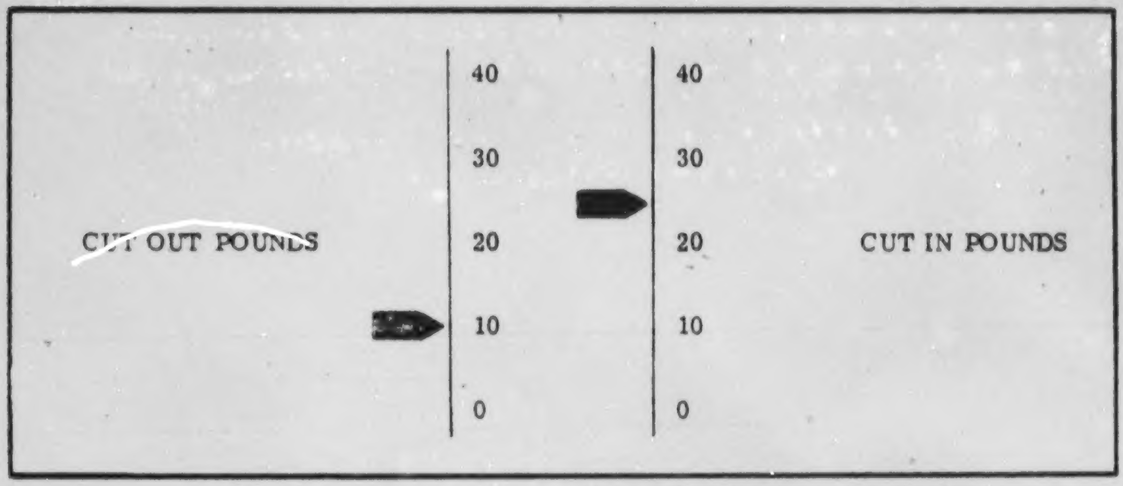

CUT OUT POUNDS
40
30
20
10
0
40
30
20
10
0
CUT IN POUNDS

Figure 34. Cut-In and Cut-Out

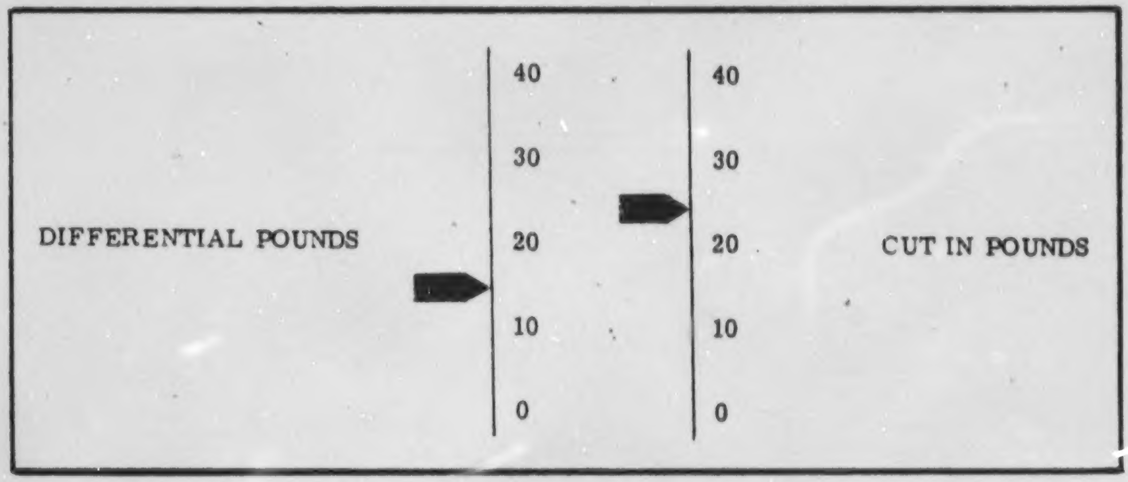

DIFFERENTIAL POUNDS
40
30
20
10
0
40
30
20
10
0
CUT IN POUNDS

Figure 35. Cut-In and Differential

Adjust a pressure control on a walk-in refrigerator using R-12 refrigerant. The desired cut-in is 25 PSI and the desired cut-out is 10 PSI. From these two values the differential will be 15 PSI. The adjusted control should appear as illustrated in Figure 34.

Setting a control for cut-in and differential requires a little thought. There are still only two settings to make. Read the scales very carefully. Remember, with this arrangement, the cut-in and the differential are set. When properly set for the same values prescribed in the previous paragraph, the control will appear as in Figure 35. It is extremely important to realize that by setting the cut-in at 25 PSI and the differential at 15 PSI, the cut-out will automatically be 10 PSI.

NOTE: Adjusting the cut-in and cut-out (or cut-in and differential) too close together will cause the unit to cycle on and off too quickly. This is known as "short-cycling."

The LPMC may be used in any application where an electrical device is controlled by sensing changes in a pressure. No matter what the use, the operation of the low pressure motor control is still the same.

HIGH PRESSURE SAFETY SWITCH (HPSSW)

The high pressure safety switch is connected to the discharge side of the compressor to protect the system against excessive head pressure. (The best place to sense the head pressure is directly from the compressor head.)

The operation is the same as the low pressure motor control except for the action of the contacts. When the head pressure rises to the cutout, the contacts open the circuit to stop the compressor motor. After the head pressure returns to normal the contacts close the circuit to restart the compressor motor.

However, some HPSSW have a "lockout" device that require the control to be reset manually once the unit has cutout due to high head pressure.

The cutout on the control should be adjusted to 20 percent above normal operating pressure for the type of refrigerant in the system.

SUMMARY

The "brain" of any refrigeration system is the motor control. It is impossible to overemphasize the importance of understanding the principle of operation, use, function, and maintenance of these delicate controls.

There are two types of motor controls, the pressure-operated type, and the temperature-operated (thermostatic). Both controls have the same purpose. They start and stop the unit at a predetermined temperature. In most cases, it is just as bad for temperatures to go too low as it is too high.

QUESTIONS

1. What is the purpose of a motor control?
2. How is a motor control wired?
3. When is a TMC required?
4. Define "Cut-in."
5. Define "Cut-out."
6. What is the difference between differential and range?
7. What are the types of motivating devices?

8. Explain the purpose of "snap action" in a motor control?
9. Where is the feeler bulb of the TMC located for a forced air, air conditioner?
10. What are the common troubles of motor controls?
11. How can the space temperature be controlled other than with a TMC?
12. What are the motivating devices of an LPMC?
13. What are two common adjustments of the LPMC?
14. Explain the term "short cycling."
15. What is the purpose of the HPSSW?
16. Where is the best place to install the HPSSW?
17. How will the contacts on the HPSSW act with an increase in head pressure?
18. What should the cut-out of the HPSSW be set at?
19. What should the cut-in of the HPSSW be set at?
20. Is the unit malfunctioning if the space temperature goes too low?

REFERENCES

1. Modern Refrigeration and Air Conditioning, Althouse, and Turnquist
2. Commercial and Industrial Refrigeration, Nelson
3. Principles of Refrigeration, Dossat

REFRIGERATION ACCESSORIES AND TROUBLE ANALYSIS

OBJECTIVE

To help you to learn the purpose, principle of operation, maintenance requirements, location, and identification of refrigeration accessories, and determine the causes of malfunction in refrigeration systems.

INTRODUCTION

So far, you have studied the units that make up a basic refrigeration system. There are several other units that, if used correctly, will materially increase the efficiency of the system. These units are called accessories. They are often advisable but not definitely required in a system. Each system must be considered individually before it can be determined if a given accessory will improve the efficiency of the system.

Trouble analysis is an organized process of elimination. The first thing to do is install the manifold gage assembly and operate the system, if possible. While the unit is operating, it will give you time to listen to the user's complaint as well as observe the symptoms of the system. In some cases, it is possible to determine the malfunction immediately, while in other cases, you may have to check several things before determining the exact trouble. A few minutes spent in observation and analysis may save hours of work later.

REFRIGERATION ACCESSORIES

Heat Exchangers

A heat exchanger (Figure 36), whether used in refrigeration, heating, or any other application is a device for transferring heat. In the refrigeration industry, a heat exchanger is used to transfer heat from the hot liquid line into the cool suction line. A typical heat exchanger installation is illustrated in Figure 37. The suction vapor (at a low temperature) goes through the inside tube in one direction and the hot liquid goes through the outside tube in the other direction. The hot liquid in the outside tubes keeps the heat exchanger from sweating. For best efficiency, the heat exchanger should be installed in the refrigerated space.

The counterflow effect of the hot liquid on cool vapor increases the heat transfer rate.

Advantages of Heat Exchangers

There are several advantages of using heat exchangers.

1. Minimizes flash gas.

2. Sweating or frosting of the suction line is minimized or eliminated.

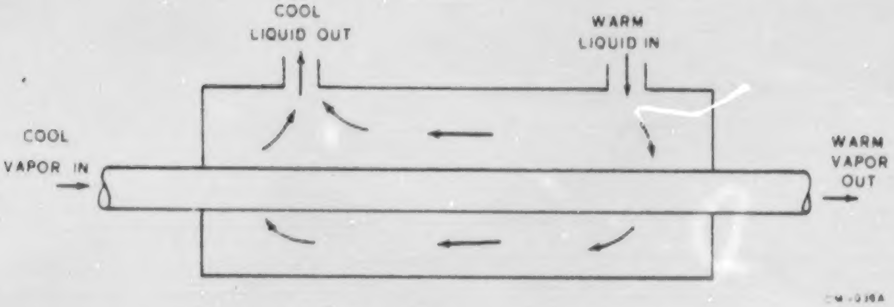

COOL
LIQUID OUT
WARM
LIQUID IN
COOL
VAPOR IN
WARM
VAPOR
OUT
CM-038A

Figure 36. Heat Exchanger (Shell and Tube)

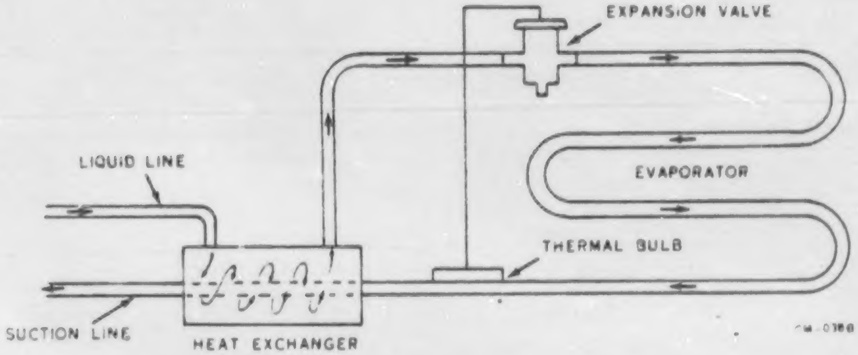

EXPANSION VALVE
LIQUID LINE
EVAPORATOR
THERMAL BULB
SUCTION LINE
HEAT EXCHANGER
CM-038B

Figure 37. Location of Heat Exchanger (Shell and Coil)

3. Flooding of liquid refrigerant to the compressor is minimized or eliminated.

4. Liquid enters the expansion valve at a lower temperature.

   This advantage is very important in low temperature application. The hot liquid that comes from the receiver must have its temperature reduced in the evaporator before it can be evaporated. This means that heat is being carried into the evaporator by the hot liquid. In passing through the expansion valve, part of the liquid vaporizes and takes up the sensible heat from the rest of the liquid, reducing its temperature to that of the evaporator.

   As an example, if one pound of 100° F liquid passed through the expansion valve into an evaporator with a temperature of 0°, about 1/16 of the pound would be vaporized reducing the 100° F liquid to 0°. Therefore, there would be only 15/16 of a pound of liquid left to produce refrigerating effect.

5. Increase compressor efficiency.

   At air conditioning temperatures, a heat exchanger will increase the volume of the suction gas enough to offset any advantage gained by reducing the amount of flash gas in the evaporator. This has caused several manufacturers of air conditioning equipment to eliminate the use of heat exchangers in their systems. However, when you consider the following conditions, it becomes obvious that heat exchangers can be an advantage to all systems.

All compressors must have an oil film on the sides of the cylinder to reduce friction between the cylinder and piston. If this film of oil is full of refrigerant each time the piston goes down, the refrigerant in the oil will evaporate in the cylinder. This reduces the amount of vapor the cylinder can remove from the evaporator. A heat exchanger will increase the temperatures of the suction gas. This, in turn, increases the temperature of the cylinder wall and the oil, which results in a thinner film of oil on the cylinder wall. The thin oil film can hold very little refrigerant so the piston can remove more vapor from the cylinder each stroke.

A heat exchanger may be manufactured by soldering the liquid line to the suction line. This is not very effective but it will help to reduce flash gas.

ACCUMULATOR

An accumulator is used to prevent liquid refrigerant from entering the compressor. The accumulator, figure 38, is a tank installed in the suction line as near the evaporator as possible. The vapor and any "flood over" liquid will enter the accumulator at point A. The liquid will fall to the bottom of the tank but the vapor can escape through line B to the compressor. Hot liquid from the receiver flows through line C and loses its heat to the liquid in the bottom of the tank. This exchange of heat forces the liquid to vaporize and is removed by the compressor through line B. After the exchange of heat, the cooled liquid continues to the expansion valve through line D. The accumulator is used on systems operating at 0°F and below.

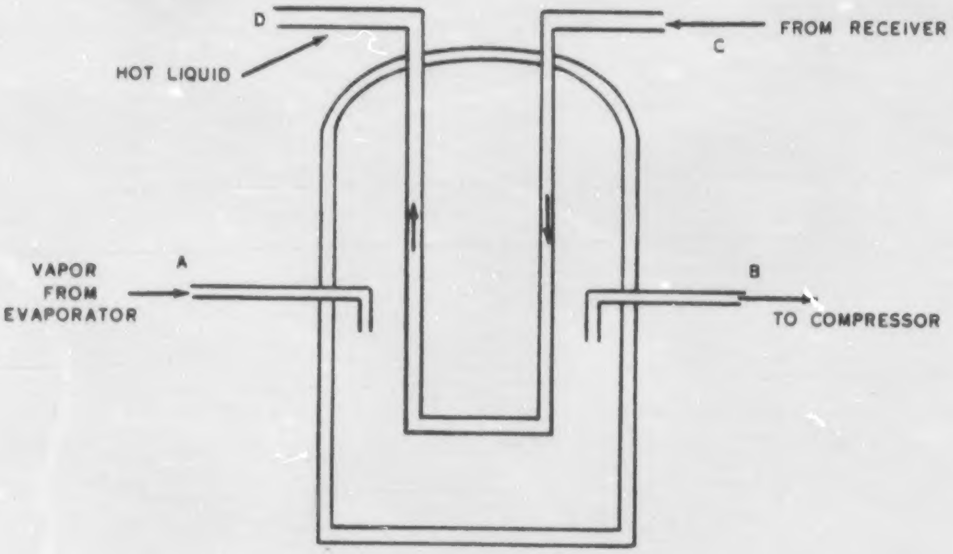


Figure 38. Accumulator

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Oil Separators

Oil separators (Figure 39) are just what the name implies. They separate the oil from the vapor. An oil separator consists of an enclosed steel cylinder with a float and needle valve inside, a gas line from the compressor, a gas line to the condenser, and an oil return line to the compressor crankcase. As the hot vapor and oil come from the compressor, the oil falls to the bottom of the oil separator and the vapor goes to the condenser. When enough oil has accumulated, the float rises, opening the needle valve (the needle valve is always below the level of the oil). The high side pressure forces the oil to return to the low side of the compressor. (See figure 40.)

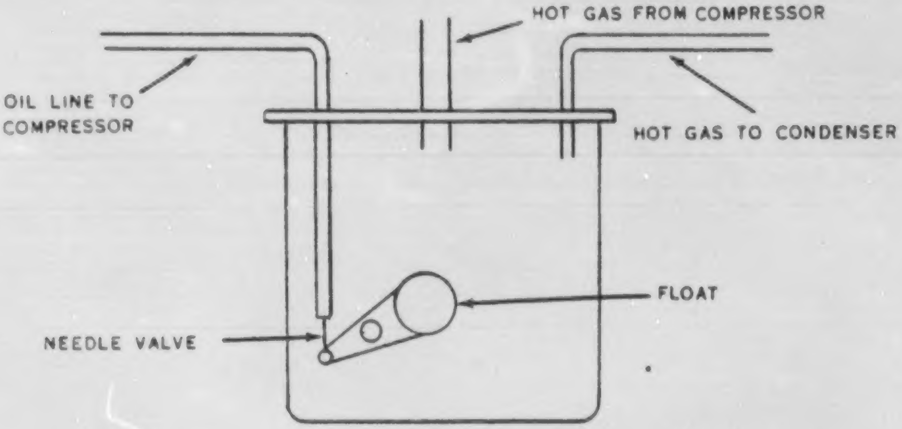


Figure 39. Oil Separator

Most expansion systems operating at temperatures above 0°F do not need an oil separator. Water coolers, low-temperature systems, and complex multiple installations operate much more efficiently if an oil separator is installed. The oil separator is insulated to prevent the refrigerant vapor from condensing in the separator and being returned to the compressor as a liquid with the oil.

Moisture

Moisture in refrigerating machines constitutes a very important problem for both the manufacturer and serviceman. Engineering has solved most of the mechanical problems in refrigeration while producers have virtually eliminated difficulties due to refrigerants unless those are mishandled. For the most part, satisfactory lubricating oils have been provided, reducing trouble from this source to a minimum. However, moisture is still found in some machines. Absence of moisture is absolutely essential for satisfactory machine operation. It is, therefore, imperative that moisture be eliminated during the manufacturing process, and the entrance of moisture in a system be guarded against in all fields of operation. If moisture does get into the system, the removal must be accomplished as soon as possible.

Moisture may get into a system as the result of:

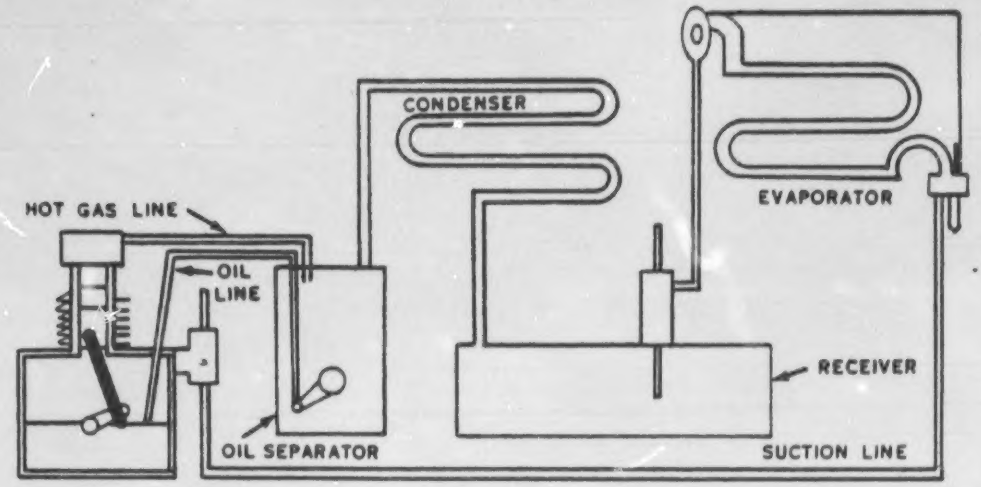


Figure 40. Location of Oil Separators

1. Faulty drying methods at the factory.
2. During assembly or service operation in the field.
3. Low side leaks (this can only happen if the low side is below atmospheric pressure or operating in a vacuum).
4. The breaking down of some hydrocarbon in the oil that produces moisture (caused by excessive operating temperature).
5. Moisture in the oil (this happens very often if the container holding the oil is left open for any period of time).
6. Moisture in the refrigerant (manufacturing methods will sometimes allow moisture to get into the refrigerant).

EFFECT OF MOISTURE. Moisture in a refrigeration system may result in one or more of the following effects:

1. "Freezing up" at the expansion device (this can only happen if the temperature is below 32°F).
2. Corrosion of metal to form sludge (this condition will stop up or clog the expansion device and screen).
3. Copper plating (this condition will result in the piston sticking in the cylinder).

Ice separates from the freon, chloride, and butane refrigerants whenever the amount of moisture is great enough and the temperature of the refrigerant low enough. This accounts for the formation of ice in the expansion valve, capillary tube, and evaporator

In low temperature units, a restricted expansion valve or capillary tube may result from the separation of wax from the oil (this condition can be eliminated by using a dewaxed oil).

The corrosion of metals occurs anytime water and refrigerants come in contact. With some metals, this corrosion is very slow, but with others, it becomes much faster. The following information will give you an idea of how and why this corrosion occurs.

1. Water and sulfur dioxide combine to form sulfurous acid (H_2SO_3). This is a mild form of the acid that is used in automobile storage batteries. All of us are familiar with the corrosion effect of battery acids.

2. Water and methyl chloride combine to form hydrochloric acid (HC_1). This acid is used to clean the rust from iron before soldering.

3. Water and Freon combine to form hydrofluoric acid (H_2F_2). This acid is used to etch glass. The combining of water and Freon is very slow and only a small amount of the acid is formed. Some servicemen in the field claim that water in a Freon system will not cause corrosion, but if the water is left in the system long enough, it will give trouble.

Driers

If, despite all precautions, some moisture finds its way into the system, it must be reduced to an absolute minimum for satisfactory operation. This can be done by the use of a desiccant (drying agent).

A drier (Figure 41) consists of a shell with a screen and filter at each end and the intervening space filled with a drying agent. The drier contains a chemical which has the property of removing moisture either by chemical or mechanical action. A drier is usually installed in the liquid line and should be placed in a vertical position with the line from the receiver connected to the bottom.

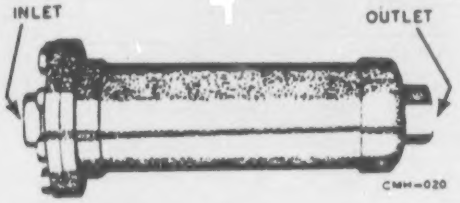


Figure 41. Drier

Calcium Chloride

This is a chemical desiccant that may be used with all refrigerants. It will not reduce the moisture content to a very low level, but is satisfactory for ordinary refrigeration systems. When calcium chloride absorbs excessive amounts of moisture, a highly corrosive liquid is formed which will escape and cause disastrous results. A drier containing this chemical should not be left in the system over 24 hours.

Calcium Oxide

This is a cheap and efficient desiccant. Its principal disadvantage is that it powders upon the absorption of excessive amounts of moisture, and the powder being very fine may pass through the filter.

Calcium Sulphate

This is in a granular form, and it has some dust but not as much as calcium oxide and with the correct filter does not cause any difficulty.

Aluminum Oxide

This desiccant removes acid and moisture by adsorption. It may be used with any refrigerant.

Silica Gel

This is the most popular drying agent. It is slower than some of the others but it may be left in the system indefinitely.

Driers are rated according to the horsepower of the compressor motor. If no data is available, use one pound of desiccant for each 10 pounds of refrigerant in the system.

Vibration Eliminators

On large installations where hard copper tubing is used, vibration eliminators must be used. Vibration eliminators are made of corrugated copper tubing with a braided bronze protecting cover. They are installed in both the discharge and suction lines and absorb the vibration of the compressor. High-pressure flexible hose is also used as a vibration eliminator, particularly in automobile air conditioning.

Surge Tanks

In an instantaneous water or beverage cooler, the warm liquid enters the cooler, causing the refrigerant to boil and generate a lot of vapor in a very short time. If this vapor is confined in a small space, the pressure will rise very rapidly. The rise in pressure will cause the compressor to start. Since the space is small, the compressor will operate for a very short time, then the pressure will be reduced and the compressor will shut off. Soon the short cycling results in undue wear and tear on the motor and the compressor. A surge tank, Figure 42, placed in the suction line will increase the space for the vapor to accumulate, and thus, it will take longer for the pressure to rise to the point where the compressor will start. After the compressor starts, a longer time will elapse before the pressure will fall to the point where the compressor will stop. The larger the surge tank is, the less tendency for the compressor to short-cycle.

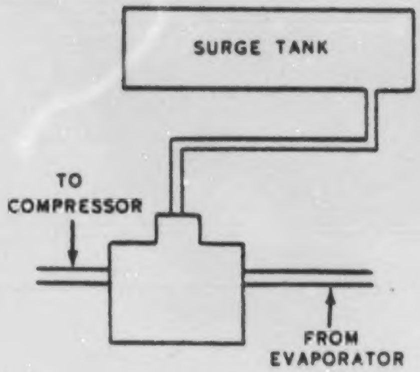


Figure 42. Surge Tank

Fusible Plugs

These plugs consist of a bushing with the inside space filled with a soft alloy. This soft alloy is the weakest point in the system. If the high side pressure should go too high, the soft alloy will blow out. The fusible plug is easily replaced and it eliminates damage to some high-priced unit in the system.

Pressure Relief Valves

These valves have the same purpose as the fusible plugs. When the pressure reaches a predetermined point, this valve will open and relieve the excessive pressure. As soon as the pressure has been reduced, the valve will close.

There are two types of these valves in common usage - the adjustable and the non-adjustable. The adjustable type can be set to open at any pressure desired. The pressure should be set approximately 20% above the maximum operating pressure. For a Freon-12 system using an air-cooled condenser, this would be 230 to 235 PSI. The nonadjustable is set at the factory. The pressure setting is normally stamped on the top of the valve. When using a valve of this type, make sure the setting is high enough so that the valve will not open during operation but is low enough to protect the equipment.

Strainers

Regardless of how careful the serviceman performs his job, he will allow some small bits of metal, dirt, or other foreign matter to enter the refrigeration system. Strainers are used to catch and hold these small foreign particles before they damage the compressor or clog up the expansion valve. Strainers are made from fine mesh wire and are designed to hold a great deal of foreign material before they become stopped up. Strainers may be located in either the liquid line or the suction line, or both. There should always be a strainer at the inlet of a refrigerant control and in the compressor just before the vapor enters the cylinder.

TYPES OF STRAINERS. There are several types of strainers.

1. Line Strainer. This strainer is installed in the liquid line. The strainer area is normally 20 times larger than the line. It is cleaned by removing the unit and blowing dry air or refrigerant through it backward.

2. "Y" Strainer. This strainer consists of a "Y"-shaped frame containing a removeable screen. The frame is installed in the line and the screen is removeable without removing the strainer frame from the line.

3. Angle Strainer. This strainer is always installed where the line makes a 90° angle. It is possible to remove and clean the screen without disturbing the lines.

4. Finger Strainer. This strainer is a fine mesh screen in a cylindrical form. It is installed at the inlet of expansion valves and in the compressor valve plate.

Mufflers

Where quiet operation is essential, specially designed mufflers may be installed to reduce compressor noise. These mufflers are installed in the discharge line near the compressor.

TROUBLE ANALYSIS

Types of Troubles

Refrigeration troubles usually fall within one of the following categories:

- ELECTRICAL TROUBLES
- REFRIGERANT CONTROL TROUBLES
- REFRIGERATION TROUBLES

The electrical system gives more trouble than the other systems combined. Therefore, it is usually best to check the electrical system first.

Electrical Trouble Analysis

The refrigeration serviceman must fully understand the use and operation of all electrical testing devices. The correct use of these testing devices makes electrical trouble analysis rather simple. Their use has been explained in previous instruction.

Absence of voltage at the motor is an indication of an open in the power circuit. Low voltage at the motor is usually caused by too many electrical units operating on the same circuit. A short is normally indicated by a blown fuse. It is usually possible to find a short by visually checking the motor circuit until you find a break or crack in the insulation. If the power circuit is in a conduit or wall, it is necessary to isolate the circuit and use a continuity meter. Some of the more frequently encountered electrical troubles are discussed in the following paragraphs.

OVERLOAD DEVICES. There are many things that will cause the overload protective device to actuate. Generally speaking, the tripping of a line starter will be indicated by a red button marked "Reset" protruding beyond the cover of the line starter. The real problem is to determine the trouble that caused the tripping device to actuate and the proper method of correcting it.

Faulty overload protection is a fairly common type of trouble. In some cases, this is caused by improper adjustment of the overload relay. Its setting is frequently excessively sensitive.

In general, however, there is a more basic program involved. In a large percentage of condensing units, the load is very light with the exception of a short period during the summer. Even then, the extremely heavy loads are usually intermittent. Thus, it is economically sound that the motor should be loaded to its limits during these periods. The overload protection must not trip under these operating conditions. A properly functioning overload device will function only when the motor is subject to damage from an overload. Variations in the manufacture of overload devices and motors, together with the variations in condensing units and their applications, affect the accuracy with which the overload protection can be applied. Some overload relays can be adjusted. However, this adjustment should be made by a competent electrician.

High ambient temperature at the motor or motor control may cause the overload to trip. Most motors are designed to operate in an ambient temperature of 100 degrees or less. If boxes and crates are stacked around the motor in such a way that ventilation is hindered, temperature around the motor may reach 200° F. Make sure all motors have sufficient ventilation. On very hot days and under heavy loads, it may be necessary to use a fan to force air over the motor and motor control.

OVERLOADING. Excessive loads may be indicated by a number of things. Overload tripping out, overheating of the motor, and failure of the motor to start are all symptoms of an excessive load. The only remedy for this condition is to remove part of the load or increase the size of the equipment; however, the repairman should first assure himself that the overload is not due to an improperly functioning refrigeration system.

A dirty air-cooled condenser will cause an increased load on the motor by increasing the head pressure at which the unit operates. The condenser can be readily cleaned with a brush or with the attachments of a vacuum cleaner. A clean condenser is more efficient in transferring heat, thus reducing running time, head pressure, and operating cost.

Water-cooled condensers develop a coating on the heat transfer surfaces when hard or dirty water is used. With the lowered rate of heat transfer, the water-regulating valve increases the flow of water in its endeavor to hold a constant head pressure. Thus, at first, a dirty water-cooled condenser causes an increase in the amount of cooling water used but the head pressure remains about normal. As the condenser gets dirtier, the water-regulating valve opens completely, but the flow of water is restricted by the dirty condenser and the head pressure increases. Obviously, under such conditions, the condenser should be cleaned periodically.

MOTOR TROUBLES. Motor heating should be verified with a thermometer unless the evidence is unquestionable, such as smoke or charred insulation. The temperature of a motor cannot be dependably determined by feeling with the hand. The thermometer bulb should be attached to the motor with putty. This eliminates its being affected by the temperature of the surrounding air. Most electrical motors are designed to operate at a temperature of 40° C (72° F) above ambient temperature. If the motor overheats, measure the current flowing through it. The current flow should not exceed the value on the data plate.

Most motors are designed to operate in an ambient temperature of 72 to 75° F. As the temperature increases, the capacity of the motor decreases. The data plate may indicate that the motor will produce one horsepower. That means it will produce one horsepower in an ambient temperature of 72 to 75° F. However, it will not produce one horsepower if it has to operate in an ambient temperature above 75°. The converse of this is also true; the motor will produce more than one horsepower if it operates in an ambient temperature of less than 72°.

Dirt in the motor may coat the windings and other heat-dissipating surfaces to such an extent that the heat is not carried away fast enough and the motor becomes overheated. This condition is often encountered in mess halls, cafeterias, sandwich shops, and other places where the air contains cooking fats. If the motor cannot be shielded from the dirt, periodic cleaning is the only answer.

The voltage can be so low that the motor will fail to start. If it does start, it will operate at less than rated RPM and the efficiency of the unit will be reduced correspondingly. Check the voltage at the motor terminals with the motor operating under maximum load. The voltage must not drop more than 10% of the rated voltage stamped on the data plate. A low voltage condition can be caused by loose or corroded connections, but usually, it is caused by overloading the circuit. If a low voltage condition is found, remove some of the electrical units from the circuit or install a new circuit.

Motor Running in the Wrong Direction. Incorrect motor rotation is the result of careless haphazard workmanship and is completely inexcusable. The lubrication systems on all compressors are designed to operate according to a given direction of rotation. If the compressor runs in the wrong direction, the lubrication system cannot operate efficiently and the compressor may be damaged. When this condition is found, check the compressor for damage and change the direction of rotation of the motor.

ELECTRICAL POWER TROUBLES. A "no" power or low power condition can be the result of opens, shorts, blown fuses, corroded or pitted points, faulty capacitors, or loose connections. It is necessary to use a process of elimination to determine which of these is causing the malfunction.

No Power. If there is no power available at the motor, use a voltmeter and check each junction box and connection for power. If there is no power at the building junction box, the trouble is in the distribution system.

If the motor will not start, the trouble usually is an "open." Most opens are caused by blown fuses. If the fuse proves to be satisfactory, use a test light or voltmeter and check for power. Repair the open, start the motor, and observe for normal operation. Blown fuses can usually be detected by inspection. However, it is not always the case. Sometimes, a fuse may look good, but in reality be blown. A fuse can be checked with an ohmmeter or test light.

A loose connection can occur in the wiring, motor control, or motor windings. A loose connection may make good contact, when the terminals of the voltmeter are pressed against it, but make poor contact when the pressure is removed. A malfunction of this type is very hard to find. It may be necessary to tighten all connections until the trouble is eliminated.

Capacitor Failure. Capacitors will fail after being in operation several years. The only remedy for a bad capacitor is to replace it.

Electrical Shock. This condition can be caused by one of two things. When one receives an electrical shock from the equipment, it is usually because it is improperly grounded or because of a shorted circuit. When static electricity is the cause, grounding of the equipment will take care of the trouble. When a power line is shorted, you must find the short and tape the line. A hot line shorted to the equipment is a very dangerous condition and should be remedied immediately.

Low Power. This condition is usually caused by placing too many electrical units on one circuit. A great number of buildings throughout the Air Force were originally wired for lights only. However, at this time these circuits are required to carry office machines, fans, air conditioners, etc. If a low power condition is found, run a new circuit.

Refrigerant Control Troubles

Some refrigeration specialists seem to think that the refrigerant control causes most of the trouble in the system. Some repairman quickly blames the expansion valve. Needless to say, this practice is both expensive and unnecessary. In reality, the expansion valve gives very little trouble. It should never be changed until all other possible malfunctions have been checked.

EXPANSION VALVE OBSTRUCTED. Sometimes the expansion valve may stick in a nearly closed position. Occasionally, dirt will obstruct the flow of refrigerant through the valve. In either case, only a small trickle of refrigerant passes through the valve. This results in a low suction pressure and a warm cooling coil. The expansion valve should be removed, cleaned (wash in R-11), readjusted, and replaced. If the needle or seat shows wear or corrosion, discard the valve and replace it with a new one.

EXPANSION VALVE CLOSED COMPLETELY. Occasionally, an expansion valve may stick in the closed position. This may be caused by corrosion, dirt, or wax. In such cases, the suction pressure will be low, but the cooling coil and suction line will be warm. A stuck valve can sometimes be loosened by striking it lightly with a rawhide hammer. However, this should be considered a temporary repair. A valve that gives trouble once will usually give trouble again unless it is cleaned correctly.

POWER ELEMENT LOSES CHARGE. The power element of an expansion valve consists of the thermal bulb, connecting tubing and the bellows or diaphragm. If the power element loses its charge, the valve will close completely, thus shutting off the refrigerant flow. One way to test for a lost charge is to remove the thermal bulb from the suction line and hold it in your hand. The heat from your hand will open the valve if the power element is not defective.

ORIFICE IN EXPANSION VALVE TOO SMALL. If the pressure drop across the expansion valve has been incorrectly computed, the orifice in the expansion valve may be too small. This will cause a high superheat in the evaporator and low suction pressure. This condition can be caused by the engineer not specifying the correct orifice or the mechanic not checking the orifice size when installing the valve. If this condition is found, increase the size of the orifice. It may be possible to remedy this condition by increasing the head pressure, but you will also increase operating cost.

EXPANSION VALVE STUCK OPEN. This condition can be caused by corrosion, dirt, or wax. Occasionally, the valve may open excessively because the thermal bulb and suction lines are not making good contact. The thermal bulb should be fastened to the suction line securely and insulated so that the temperature of the bulb and suction line will be approximately the same. When the expansion valve remains open, it causes a high suction pressure, frosting of the suction line, and flooding of the evaporator.

EXPANSION VALVE OUT OF ADJUSTMENT. This condition is usually caused by inexperienced personnel trying to adjust the control. Readjust the control and advise the user to leave it alone.

GAS IN THE LIQUID LINE. It takes a very small amount of gas in the liquid line to reduce the capacity of the expansion valve tremendously. Gas can be caused in the liquid line by a shortage of refrigerant, partially plugged strainer or drier, excessive pressure loss in the liquid line, or a large heat gain in the liquid line. If the liquid line passes near a steam coil or heating element, it may pick up enough heat to cause some "flashing" in the liquid line.

When bubbles are noted in the sight glass, the cause must be determined and then corrected.

INCORRECT LOCATION OF EXTERNAL EQUALIZER LINE. When an externally equalized valve is used, the equalizer connection should be made at a point [illegible] suction line that will reflect the pressure existing in the line at bulb location.

INSUFFICIENT PRESSURE DROP ACROSS THE VALVE. Expansion valves are normally designed for a 60-PSI pressure drop. If the net pressure drop across the valve is less than 60 PSI, the valve capacity will be reduced accordingly. Low condensing pressures or excessive liquid line pressure losses are usually the cause of insufficient pressure drop across the valve.

GAS-CHARGED CONDENSATION. When using gas-charged valves, the body of the valve must be warmer than the thermal bulb. If the body of the valve becomes colder than the bulb, the charge may condense at the diaphragm, causing the valve to lose control and close.

If gas condensation is suspected, heat the valve body with warm water and observe the results. If this corrects the malfunction, the expansion valve must be relocated or exchanged for one with a liquid charge.

INCORRECT BULB INSTALLATION. The thermal bulb must be securely fastened to the suction line with two bulb straps and must be insulated from ambient temperatures. A loosely connected thermal bulb or ambient temperatures can cause very erratic operation. Check to make sure the thermal bulb is not trapped.

Refrigeration Troubles

The best procedure for diagnosing refrigeration troubles is to observe the operating pressures. As long as the unit is properly designed and sized, both suction and head pressure should correspond to the pressure temperature chart.

SUCTION PRESSURE. Suction pressure of the system indicated by the suction pressure gage should correspond to a temperature approximately 10° F. less than the temperature of a thermometer placed on the cooling coil.

> EXAMPLE: A system using R-12 and having a suction pressure of 37 PSIG will have an evaporator temperature of approximately 50° F. By subtracting 10° F. for the temperature difference between the inside and outside cooling coil condition, and by checking the P-T Chart, we can determine the temperature of the refrigerant in the suction line.

HEAD PRESSURE. To determine the proper operating head pressure on forced convection air-cooled units, add 30 degrees to the ambient air temperature and obtain the head pressure from the P-T Chart. The 30 degrees are an average.

> EXAMPLE: If ambient temperature is 90°, add 30 degrees (this equals 120° F.). With a system using R-12, a 120-degree temperature equals 157.1 PSI. This is an approximation and a few degrees or pounds variance from this may be considered normal operating conditions.

The same procedure is employed to determine the head pressure of a water-cooled unit. However, only 25 degrees are added to the temperature of the inlet water.

EXAMPLE: If inlet water temperature is 75° F, add 25 degrees (this equals 100° F.). With a system using R-12, a 100° F. temperature should have a corresponding pressure of 116.9 PSI.

ABNORMAL PRESSURES. Pressures that are too low or too high are considered abnormal. One condition is just as bad as the other.

Low Suction Pressure. Low suction pressure may be caused by low charge, obstructed liquid line, motor control out of adjustment, or not enough air passing over the evaporator.

A low charge condition is usually indicated by bubbles in the sight glass, hissing at the expansion valve, a warm suction line, a cool liquid line, low suction pressure, or a warm evaporator. Since these conditions also can be caused by a restriction in the liquid line, it may be necessary to check for both a low charge and a restriction to determine which is causing the trouble. If a unit is found to be low on charge, find and repair the leak before recharging. If the unit is low on charge, there has to be a leak some place where the refrigerant has escaped. If you charge the unit without stopping the leak, you will have to recharge again.

Restrictions that cause low suction pressure can usually be found at screens, valves, capillary tubes, and soldered joints (see Figures 43 and 44). A restriction in the liquid line is usually indicated by a drop in temperature at the point of the restriction. Restrictions are usually caused by dirt, wax, small pieces of metal, solder, and other contaminants. When a restriction is found, it is just as important to determine the cause of the contaminants as it is to remove the restriction. A badly contaminated system may require disassemblying and cleaning before satisfactory performance can be expected.

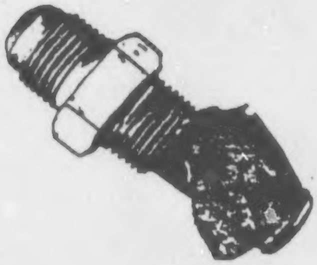
When low suction pressure is attributed to insufficient air passing over the evaporator, the cause can usually be traced as a dirty filter or placing of boxes and foodstuff in such a way as to restrict the flow of air. Clean the filter, rearrange the foodstuff, and instruct the user on the correct operation. A burned-out motor on a forced convection evaporator will cause this same condition.

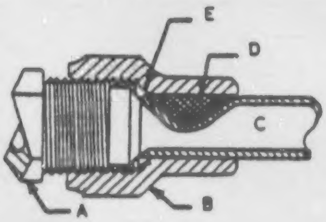
High Suction Pressure. This condition is caused by malfunctioning expansion valves, inefficient compressors, high heat load, and high head pressure.

1. Inefficient Compressor. After several years of operation, the valves, rings, and pistons in the compressor become worn; this results in low compressor capacity and a high suction pressure. When this condition is found, repair, or replace the compressor.

2. High Heat Load. Each condensing unit is designed to handle a given size load at a given temperature. If the size of the load increases, the equipment must also be increased.

Low Head Pressure. This condition can be caused by low charge, inefficient compressor, cooling medium too cold, or too much cooling medium. Most refrigerant controls are designed to operate with a pressure drop of at least 60 PSI. If the pressure drop is not 60 PSI, the amount of refrigerant passing through the expansion valve will also be reduced. This results in a starved evaporator. The head pressure can reduce to such a degree that flash gas will occur in the liquid line, causing bubbles in the sight glass that will give a false indication of a low charge.





An illustration of what happens when moisture freezes between the nut and tubing.

A - Fitting
B - Flare Nut
C - Tubing
D - Ice Formation
E - Flare Being Pulled Out of Place

Figure 43. Clogged Strainer

Figure 44. Ice between Tubing and Flare Nut

1. Low Charge. A low charge results in a reduced amount of heat being removed from the evaporator. Therefore, the condenser does not have as much heat to dissipate and the head pressure remains low.

2. Cooling Medium Too Cold. This happens very often on air-cooled units in cold areas. Each application has to be handled independently. It may be possible to restrict the air flow through the condenser or perhaps supply air at room temperature to the condenser. In some cases, it may be necessary to use an electrical heating element to heat the air before it goes through the condenser. Where several condensing units are being used in one place, it may be possible to install all of them in an equipment room and maintain the temperature in the room between 70 and 100° F. This procedure is used very often in supermarkets and large drug stores. In case of water-cooled units, restricting the flow of water will usually raise the head pressures.

High Head Pressure. Excessive head pressures will reduce the compressor capacity, cause the unit to be noisy, and increase the operating cost. High head pressure can be caused by an overcharge of refrigerant, noncondensible gas in the condenser, cooling medium too hot, flow of cooling medium restricted, or a dirty condenser.

1. Overcharge of Refrigerant. Some refrigeration specialists seem to think that adding a little refrigerant will correct all malfunctions. One man will add a little gas and then leave without finding or repairing the real trouble. The trouble is still there, so two or three days later, the user requests another service call. The next man adds a little more gas. This process is repeated until the head pressure gets so high that the unit quits completely or the compressor is damaged. Adding refrigerant every time you put the gages on a system is a very dangerous practice especially on capillary tube systems. If the unit is overcharged, purge the excess refrigerant to the atmosphere and determine and correct the cause of the original trouble.

2. Noncondensible Gases in the Condenser. A refrigeration specialist speaks of noncondensible gases. This is a misnomer as all gases are condensible if the pressure is high enough and the cooling medium cool enough. In the refrigeration industry noncondensible gases are those gases that will not condense in a normal refrigeration system. Normally, when we speak of noncondensible gases, we are referring to air. Noncondensible gases can enter the system during maintenance or when there is a leak in the low side and the low side pressure goes below 0 PSIG. If air is found in the system, purge it to the atmosphere. Purging will not eliminate all the air from a system, but you can purge enough to lower the head pressure to normal.

   When air is found in the system, the low side must be checked very closely for leaks. Air in the system indicates moisture. Therefore, a new drier should be installed.

3. Cooling Medium Too Hot. Occasionally, boxes and material are stacked in such a way that the discharge air from the condenser will be recirculated through the condenser. Providing plenty of ventilation will eliminate this problem. If it is necessary for the unit to operate in a boiler room or other hot area, it may be necessary to use a water-cooled condenser. If it is not possible to reduce the temperature of the cooling air or use a water-cooled condenser, replace the expansion valve with one having a greater pressure drop and increase the size of the motor. Both R-12 and R-22 systems will operate as long as the temperature and pressure remain below the critical limit.

   In a water-cooled condenser, the water temperature is seldom too hot. If the water is too hot, it usually can be cooled by running it through a water tower before being used in the condenser.

4. Cooling Medium Restricted. In water-cooled units, the condenser may become clogged with dirt, scale, and corrosion. The remedy is to clean the condenser and water pipes.

   In air-cooled units, providing plenty of ventilation will usually reduce the head pressure.

5. Dirty Condenser. All condensers get dirty and must be cleaned. However, those operating in areas such as mess halls where the air is full of cooking fats get dirtier and cause more trouble than any of the others.

Service Charts

The general operation of the system is very important in diagnosing refrigeration troubles. Such things as short cycling, erratic or continuous running, and abnormal frosting of the suction line should be noted and considered when attempting to determine the cause of a refrigeration malfunction.

A modern refrigeration machine should be comparatively quiet. The faint hum of the motor and perhaps a subdued clicking of the compressor valves should be expected as normal. A hissing sound at the refrigerant control indicates a low refrigerant charge. Any loud noises coming from the compressor indicate mechanical defect.

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Service charts are especially helpful to a beginner in analyzing troubles. These charts should be used only as a guide. As you gain experience and knowledge, the use of these charts will become less important. The following pages contain several Service Charts with associated complaints and systems. Study them and keep them handy; you will use them many times in this course.

SERVICE CHART NO. 1

COMPLAINT: Unit will not operate.

TYPE OF SYSTEM: Any

Observations	Possible Trouble	Remedy
Unit will not start	Electrical Troubles	
	1. No power at main junction box	1. Check voltage at the main junction box
	2. Blown fuse	2. Replace the fuse
	3. Open switch	3. Close the switch
	4. Open in the power line	4. Check for an open line
	Motor Control Troubles	
	1. Out of adjustment	1. Adjust control
	2. Points corroded	2. Clean the points
	3. Broken power element	3. Replace control
	4. Broken spring	4. Replace control
	5. Kinked or broken capillary tube	5. Replace control
	Thermal Overload Tripped	
	1. Belt too tight	1. Loosen belt
	2. Low voltage	2. Check voltage at the motor
	3. Motor needs lubrication	3. Oil motor bearings
	4. Compressor stuck	4. Replace compressor
	Motor Troubles	
	1. Motor burned out	1. Replace motor
	2. Start winding burned out	2. Replace motor
	3. Capacitor burned out	3. Replace capacitor

SERVICE CHART NO. 2

COMPLAINT: Unit operates but will not cool.

TYPE OF SYSTEM: Any with pressure motor control

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Observations	Possible Trouble	Remedy
Suction pressure: Below cut-in point	Refrigerant Flow Restricted	
Head pressure below normal for an operating unit	1. Kink in the liquid line	1. Replace the line
	2. Closed receiver valve	2. Open the valve
	3. Restriction in the liquid line	3. Remove the restriction
	4. Low refrigerant charge	4. Charge system
	5. Refrigerant control plugged	5. Remove and clean the refrigerant control

SERVICE CHART NO. 3

COMPLAINT: Condensing Unit Short Cycles TYPE OF SYSTEM: Any

Observations	Possible Trouble	Remedy
Suction line warm	1. Motor control faulty	1. Replace control
	2. Motor control differntial too narrow	2. Adjust differential
Suction pressure: Normal to high	3. Low voltage	3. Call electrical repair shop
High side pressure: Low	4. Motor defective	4. Replace motor

SERVICE CHART NO. 4

COMPLAINT: Unit operates but box temperature is too high.

TYPE OF SYSTEM: Thermostatic Expansion Valve

Observations	Possible Trouble	Remedy
Suction pressure low	1. System low on refrigerant	1. Locate and repair leak
Head pressure low	2. Ice, wax, or dirt plugging the expansion valve	2. Remove and clean expansion valve
Box temperature high	3. Partial restriction in the liquid line	3. Find and remove restriction
	4. Expansion valve faulty	4. Replace expansion valve
	5. Superheat setting too high	5. Adjust superheat
	6. Thermal bulb not correctly located	6. Relocate thermal bulb

SERVICE CHART NO. 5

COMPLAINT: Condensing Unit Short Cycles TYPE OF SYSTEM: Any with H. P. M. C.

Observations	Possible Trouble	Remedy
Suction line: Warm	1. Condenser dirty	1. Clean condenser
Suction pressure: Normal to high	2. Air to or from the condenser restricted	2. Remove restriction
	3. Condenser area poorly ventilated	3. Ventilate area or use water-cooled condenser
Head pressure: High	4. Insufficient water to the water-cooled condenser	4. Remove the restriction in the water line. Use longer line
	5. Water pressure too low	5. Install larger pump
	6. Supply water too warm	6. Use water tower or evaporative condenser
	7. Air in the system	7. Purge
		TYPE OF SYSTEM: L. P. M. C.
Suction line: Cold	1. Evaporator fan running too slow	1. Tighten belt. Install larger fan motor
Suction pressure: Low	2. Condensing unit too large for evaporator	2. Replace condensing unit. Reduce the speed of the compressor
Discharge pressure: Low		
Evaporator: Frosted	3. Air across the evaporator restricted	3. Move foodstuff to allow free movement of air across the evaporator
Box temperature: High		

SERVICE CHART NO. 6

COMPLAINT: Condensing Unit Runs Too Long or Continuously

TYPE OF SYSTEM: Any

Observations	Possible Trouble	Remedy
Evaporator entirely or partially defrosted	1. Low compressor efficiency	1. Repair compressor
	2. Belt slipping	2. Tighten belt
Suction line: Warm	3. Low voltage	3. Call electrical repair shop
Suction pressure: High	4. Undercharged	4. Recharge
Head pressure: Low		

SERVICE CHART NO. 8

COMPLAINT: Odors

TYPE OF SYSTEM: Any

Observations	Possible Trouble	Remedy
Odor in refrigerated space	1. Refrigerated space dirty 2. Food spoiled 3. No trap in condensate water line	1. Clean 2. Remove spoiled food 3. Install trap
Odor outside of cabinet	1. Belt slipping 2. Insulation on electric lines burned 3. Motor running hot	1. Replace belt 2. Determine the cause of the trouble 3. Determine the cause of the trouble and eliminate it

SUMMARY

Various accessories are used in refrigeration systems to increase the operational efficiency of the system. Each system and application must be considered before we can determine if a given accessory should be installed in the system. Some of the main points to remember when installing accessories are:

1. Heat Exchanger. Should be installed as near the evaporator as possible with a counterflow action.
2. Oil Separators. Normally used in system operating below 0° F. but is not a cure -all for all cases of oil logging.
3. Desiccants. Silica gel is the best drying agent but is slow in acting.
4. Pressure Relief Valves. Must be set high enough to prevent opening during normal operation but low enough to protect the system.

Trouble analysis is primarily a process of elimination. A large portion of service troubles may be found in the electrical circuits. For this reason, it is advisable to check the electrical circuits before proceeding to the refrigeration system. In analyzing a refrigeration system trouble, you must take into account the following things:

1. Temperature of the refrigerated space
2. Evaporator temperature
3. Liquid, suction, and discharge line temperature
4. Suction and discharge pressures
5. General operation conditions

Competence in trouble analysis will be gained by field experience or a thorough knowledge of the principles of refrigeration.

SERVICE CHART NO. 6 (Continued)

Evaporator entirely or partially defrosted Suction line: Warm Suction pressure: High Head pressure: High	1. Condensing unit overloaded 2. Condenser too small	1. Use larger condensing unit 2. Increase the size of the condenser
TYPE OF SYSTEM: Thermostatic Expansion Valve		
Evaporator not cold enough Suction line: Cool Suction pressure: High Head pressure: Low	1. Expansion valve out of adjustment 2. Thermal bulb not correctly located 3. Expansion valve sticking open 4. Expansion valve faulty	1. Readjust expansion valve 2. Relocate thermal bulb 3. Remove, clean, and test expansion valve 4. Replace expansion valve

SERVICE CHART NO. 7

COMPLAINT: Unit Too Noisy

TYPE OF SYSTEM: Any

Observations	Possible Trouble	Remedy
Compressor is noisy	1. Compressor mounting bolts loose 2. Shipping bolts installed 3. Belt squeaks	1. Tighten bolts 2. Remove shipping bolts 3. Check pulleys for alignment. Use belt dressing. Replace belt
	4. Oil level too low 5. Oil level too high 6. Air in the system 7. Overcharge of refrigerant 8. Compressor worn	4. Add oil 5. Remove excess oil 6. Purge the air 7. Remove the excess refrigerant 8. Repair the compressor
Motor is noisy	1. Needs lubrication 2. Brushes squeak 3. Motor bearing worn 4. Mounting bolts loose	1. Oil 2. Replace motor 3. Replace motor 4. Tighten
Complete unit is noisy	1. Piping vibrates 2. Floor vibrates	1. Install vibration eliminators. Place a coil of tubing in each line 2. Install vibration absorbers. Strengthen the floor. Move unit

QUESTIONS

1. Explain the purpose of heat exchangers.
2. How does a heat exchanger increase efficiency?
3. Where is the best place to install a heat exchanger?
4. What are the types of heat exchangers?
5. What is the purpose of counterflow within the heat exchanger?
6. What is the purpose of the accumulator?
7. When is the accumulator used?
8. Where is the oil separator installed?
9. When is the oil separator used?
10. Why is the oil separator insulated?
11. What are the effects of moisture on a system operating above 32°F?
12. Name two types of desiccant found in driers?
13. How is a drier installed?
14. Where is the vibration eliminator installed?
15. What is the purpose of the surge tank?
16. What is the purpose of pressure relief valves?
17. What are the types of strainers?
18. Where is the muffler installed?
19. What are the three main refrigeration troubles?
20. What is the first thing to check if the motor will not run?
21. What is the usual cause of low voltage at the motor?
22. What should be done if the capacitor malfunctions?
23. How can the power element of the thermostatic expansion valve be checked?
24. A hissing expansion valve would most probably indicate____________.

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25. What is the normal operating temperature of the forced air condensing unit at 80°F ambient air temperature?

26. What should the HPSSW be adjusted to for an R-12 system at 100°F ambient air temperature?

27. What is a sign of a restricted drier?

28. Name two malfunctions that could cause high discharge pressure?

29. What two sounds are normally heard from an operating condensing unit?

REFERENCES

1. Modern Refrigeration and Air Conditioning, Althouse and Turnquist
2. Commercial and Industrial Refrigeration, Nelson
3. Refrigeration, Air Conditioning, and Cold Storage, Gunther
4. Refrigeration Data Book

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WORKBOOK 3ABR54530-IV-1-P1 thru -3-P6

Department of Civil Engineering Training

Refrigeration and Air Conditioning Specialist

REFRIGERATION CONTROLS AND ACCESSORIES

January 1975

SHEPPARD AIR FORCE BASE

11-7

Designed For ATC Course Use

DO NOT USE ON THE JOB

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REFRIGERATION AND AIR-CONDITIONING SPECIALIST

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This supersedes WB 3ABR54530-IV-1-P1 thru -3-P6, 17 September 1973. Previous Edition will be used.

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Dept of Civil Engineering Tng
Sheppard AFB, Texas

WB 3ABR54530-IV-1-P1
21 January 1975

INSTALLATION AND ADJUSTMENT OF AUTOMATIC EXPANSION VALVES

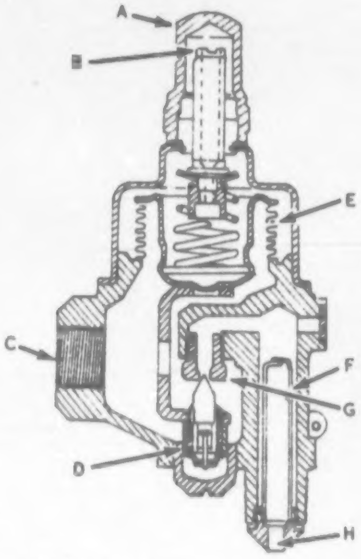
OBJECTIVE

To be able to install and adjust an automatic expansion valve.

INSTRUCTIONS

1. Color the high-pressure liquid passages red (see figure 1).
2. Color the chamber containing evaporator pressure blue.
3. Color the area affected by atomospheric pressure green.
4. Have instructor check your work before proceeding.

Checked by ____________________
Instructor



A. ADJUSTMENT COVER
B. ADJUSTING SCREW
C. OUTLET
D. NEEDLE ASSEMBLY
E. BODY BELLOWS
F. INLET STRAINER
G. SEAT
H. INLET

Figure 1. Automatic Expansion Valve Parts (Bellows Type)

PROCEDURE

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

PREOPERATIONAL CHECKLIST

1. Check for loose electrical connections and frayed wires.
2. Make sure power cord has a grounding device and spark arrestor.
3. Check for broken or loose refrigerant lines.
4. Make sure cut-out setting on high-pressure switch is NOT set above 160 p.s.i.
5. Make sure ALL hand valves are in the OPEN position.
6. Put on goggles and remove jewelry.
7. Install manifold gauge assembly.
8. Place service valves in GAUGE position.

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OPERATIONAL SAFETY CHECK

1. Remove all obstructions from trainer (rags, tools, tubing, etc.).
2. Plug the trainer electrical cable into wall outlet (twist slightly to right to lock plug into outlet).
3. Place switches for evaporator and condenser fan to ON position.
4. Place selector knob on the line starter to the AUTO position.

   NOTE: The instructor may require you to use the MANUAL position; additional instructions will be given.
5. Turn MASTER switch to ON position.
6. Check operating pressure.

OPERATION

1. Pump down the unit 1-5 p.s.i.
2. Close evaporator hand valves.
3. Fabricate all necessary lines and install the automatic expansion valve.
4. Purge the unit from the inlet hand valve to the outlet hand valve.
5. Check for leaks.
6. Open evaporator hand valves.
7. Operate the unit.
8. Observe the low side pressure gauge.
9. Adjust the automatic expansion valve to maintain 5 p.s.i.

   NOTE: Turn the adjusting screw (B) clockwise to raise the pressure and counter-clockwise to lower the pressure.

   CAUTION: You should never turn the adjusting screw more than one quarter (1/4) turn at a time.
10. Allow sufficient time for the evaporator pressure to stabilize before further adjustments are made.
11. What is the temperature of the refrigerant in the evaporator? ____________________
12. Is there a frost line on the evaporator? ____________ Why? ____________________

    ____
13. Would it be possible to get liquid back to the compressor? ____________________

14. Have the instructor check your work before proceeding.

Checked by ______________________
Instructor

15. Adjust the automatic expansion valve to maintain 10 p.s.i.

16. What is the temperature of the refrigerant in the evaporator? ____________

17. Adjust the expansion valve until the frost line extends approximately 2 feet down the suction line.

18. What is the low side pressure? ______________________________

____

19. What is the temperature of the liquid refrigerant in the evaporator? ________

20. What is the temperature of the vapor at the end of the frost line? __________

Why? ______________________________________

21. How would an increase in heat load affect the following items?

    a. Low side pressure: ______________________________
    b. Frost line: ______________________________
    c. Temperature of liquid refrigerant: ______________________

22. Have the instructor check your work.

Checked by ______________________
Instructor

POSTOPERATIONAL SHUTDOWN

1. Place all switches in the OFF position.
2. Unplug the trainer electrical cable from the wall outlet.
3. Roll up electrical cable and place it inside the trainer cabinet.
4. Back seat service valves.
5. Remove manifold gauge assembly.
6. Clean trainer by removing tools and materials and wiping down trainer and floor area.
7. Leave evaporator door open.

CHECKING AND INSTALLING THERMOSTATIC EXPANSION VALVES

OBJECTIVE

To be able to adjust the superheat setting, checking for needle valve leakage and checking the power element on thermostatic expansion valves, and install thermostatic expansion valves.

INSTALLING THERMOSTATIC EXPANSION VALVES

NOTE TO INSTRUCTOR: Furnish each two students with a thermostatic expansion valve.

PROCEDURE

Accomplish all preoperational and operational safety checks listed in WB 3ABR54530-IV-1-P1 prior to operation of the trainer and observe the listed procedures closely during all operations.

INSTRUCTIONS

1. List the following information concerning the valve.

   a. Refrigerant ________________________________

   b. Capacity ________________________________

   c. M.O.P. if indicated ________________________________

   d. Manufacturer ________________________________

   e. Inlet size ________________________________

   f. Outlet size ________________________________

2. Remove and clean the strainer if necessary.

OPERATION

1. Pump down the unit 1-5 p.s.i.
2. Close evaporator hand valves.
3. Remove the old expansion valve.
4. If necessary, fabricate and install the line from the hand valve to the expansion valve.

5. Install the new expansion valve.

6. Purge the unit from the inlet hand valve to the outlet hand valve.

7. Open evaporator hand valves.

8. Check for and repair all leaks.

9. Give the position of the thermal bulb location on the following suction line sizes.

   a. Less than 7/8 inch____________________

   b. 7/8 up to 2 1/8 inch____________________

   c. 2 1/8 inch and up____________________

10. Define a trapped thermal bulb.____________________

____

11. Explain the effects of a trapped thermal bulb.____________________

____

12. Have the instructor check your work before proceeding.

Checked by____________________
Instructor

13. Observe the sight glass and charge the unit if necessary.

14. List the low side pressure after:

   a. 1 minute of operation____________________

   b. 2 minutes of operation____________________

   c. 5 minutes of operation____________________

   d. 10 minutes of operation____________________

15. If an expansion valve is adjusted to maintain 10° superheat at 32°F, what will be the superheat at 5°F?____________________

16. Under what conditions is it permissible to:

    a. increase the superheat? ________________________________

    b. Decrease the superheat? ________________________________

    NOTE: Superheat = suction pressure converted to temperature, subtracted from the superheat thermometer temperature.

17. What is the superheat? ________________________________

    ____

18. Adjust the expansion valve to maintain 10 degrees superheat:

    a. Clockwise increases superheat.

    b. One-fourth turn adjustment at a time.

19. Have the instructor check your work.

Checked by ________________________
Instructor

20. Repeat this project as often as time permits.

POSTOPERATIONAL SHUTDOWN

1. Place all switches in the OFF position.
2. Unplug the trainer electrical cable from the wall outlet.
3. Roll up the electrical cable and place it inside the trainer cabinet.
4. Backseat service valves.
5. Remove manifold gauge assembly.
6. Clean trainer by removing tools and materials and by wiping down trainer and floor area.
7. Leave evaporator door open.

INSTALLING THERMOSTATIC EXPANSION VALVE WITH EXTERNAL EQUALIZER LINE

OBJECTIVE: To be able to install a thermostatic expansion valve with an external equalizer line.

INSTRUCTIONS

1. List the following information concerning the valve:

   a. Refrigerant ______________________________

   b. Capacity ______________________________

   c. MOP (if indicated) ______________________________

   d. Manufacturer ______________________________

   e. Inlet size ______________________________

   f. Outlet size ______________________________

2. Remove and clean the finger screen.

PROCEDURE

Accomplish all preoperational and operational safety checks listed in WB 3ABR54530-IV-1-P1 prior to operation of the trainer and observe the listed procedures closely during all operations.

OPERATION

1. Pump down the unit.

2. Close evaporator hand valves.

3. Remove old expansion valve.

4. Fabricate and install the line from the hand valve to the expansion valve if necessary.

5. Install the new expansion valve.

6. Install the equalizer line on port provided.

7. Give the position of the thermal bulb on the following size lines:

   a. Less than 7/8 inch ______________________________

   b. 7/8 inch to 2 1/8 inch ______________________________

   c. 2 1/8 inch or more ______________________________

8. Where should the equalizer line be installed? ________________________________

____

9. Have the instructor check your work before proceeding.

Checked by ________________________
Instructor

10. Check for leaks.

11. Repair all leaks as necessary.

12. Purge all lines that have been open.

13. Open evaporator hand valves.

14. Place the unit in operation.

15. Observe the sight glass and charge the unit if necessary.

16. List the low side pressure after:

   a. 1 minute of operation ________________________________

   b. 2 minutes of operation ________________________________

   c. 5 minutes of operation ________________________________

   d. 10 minutes of operation ________________________________

17. If an expansion valve is adjusted to maintain 10° superheat at $32^{\circ}F$, what will be the superheat at $5^{\circ}F$? ________________________________

18. Under what conditions is it permissible to:

   a. Increase the superheat? ________________________________

   b. Decrease the superheat? ________________________________

NOTE: Superheat = suction pressure converted to temperature, subtracted from the superheat thermometer temperature.

19. What is the superheat?

20. Adjust the expansion valve to maintain 10 degrees superheat:

   a. Clockwise increases superheat.

   b. One-fourth turn adjustment at a time.

21. Have the instructor check your work.

Checked by________________________
Instructor

22. Repeat this project as often as time permits.

POSTOPERATIONAL SHUTDOWN

1. Place all switches in the OFF position.
2. Unplug the trainer electrical cable from the wall outlet.
3. Roll up the electrical cable and place it inside the trainer cabinet.
4. Backseat service valves.
5. Remove manifold gauge assembly.
6. Clean trainer by removing tools and materials and by wiping down trainer and floor area.
7. Leave evaporator door open.

INSTALLING AND ADJUSTING THERMOSTATIC MOTOR CONTROLS

OBJECTIVE: To be able to:

- Adjust a thermostatic motor control.
- Install a thermostatic motor control.

MOTOR AND MOTOR CONTROL CIRCUIT

1. Below is an incomplete electrical diagram of a refrigeration system, including the motor control. Complete the diagram in proper sequence. Then indicate by arrows the current flow through the circuit during one alternation.

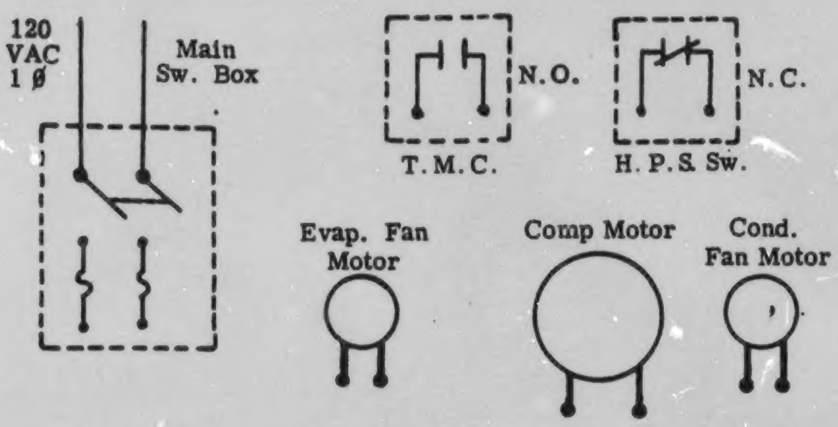

Figure 2. Typical Circuit Not Using Magnetic Line Starter

2. What safety precautions should be taken when connecting a thermostatic motor control? ______________________________

3. Ask the instructor to check your diagram.

Checked by ______________________________
Instructor

INSPECTION OF MOTOR CONTROL

1. Remove the cover from the control.
2. Inspect for evidence of dirt, foreign matter, and corrosion.

3. Clean if necessary.

NOTE: Compressed air will usually remove dirt and foreign matter. Oil and grease can be removed with an approved solvent or R-11.

CAUTION: DO NOT USE CARBON TETRACHLORIDE.

4. If the points or other working parts are badly corroded, remove the old control and replace it with a new one.

NOTE: Reverse installation procedure for removal.

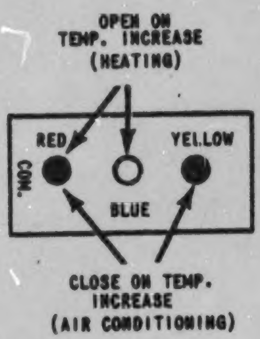
OPEN ON TEMP. INCREASE (HEATING)
RED
COM.
BLUE
YELLOW
CLOSE ON TEMP. INCREASE (AIR CONDITIONING)

Figure 3.

INSTALLATION, IF REQUIRED

1. Mount the control on the trainer.
2. Insert the thermal bulb in the refrigerated space.

CAUTION: Do not kink or break the capillary tube.

Disconnect power.

3. Wire the control in series (figure 3).
4. Have the instructor check your work before proceeding.

Checked by________________________
Instructor

PROCEDURE

Accomplish all preoperational and operational safety checks listed in WB 3ABR54530-IV-1-P1 prior to operation of the trainer and observe the listed procedures closely during all operations.

OPERATION

NOTE: Part I is to be accomplished on motor controls and accessories trainer; part II is for discussion purposes only.

PART I

1. Adjust the control to maintain an average box temperature of 30° with a differential of 10° (figure 4).
2. What is the cut-in?______________

____

____

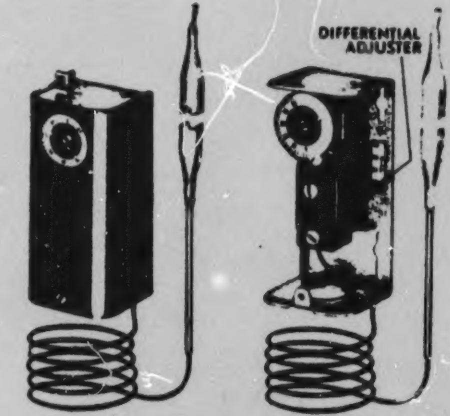

Figure 4. Remote Bulb Thermostatic Motor Control

3. What is the cut-out? ____

____

4. Replace cover (see figure 4).

5. Operate the unit.

6. Adjust the range for a maximum box temperature of 40 degrees.

7. What is the cut-in? ____

8. What is the cut-out? ____

9. What is the differential? ____

10. Observe very closely and record the box temperature when the unit cuts out.

____

11. Record the temperature when the unit cuts in. ____________________

12. Do these temperatures vary from the indication on the decal? If so, why?

____

____

13. Stop the unit.

14. Adjust the cut-out for 25°F.

15. What is the cut-in? ____

16. What is the differential? ____

17. What is the range? ____

18. Would it be possible to adjust the cut-out for 45°F? ____________________

____

19. Ask the instructor to check your work.

Checked by ______________________________
Instructor

POSTOPERATIONAL SHUTDOWN

1. Place all switches in the OFF position.

2. Unplug the trainer electrical cable from the wall outlet.

3. Roll up electrical cable and place it inside the trainer cabinet.

4. Remove manifold gauge assembly.

5. Clean trainer by removing tools and materials and wiping down trainer and floor area.

6. Leave evaporator door open.

PART II

1. Set the cut-in at 45°.

2. Set the differential at 10°.

3. What is the cut-out? ______________________________

4. Assemble the knob and lock plate for range adjustment (see figure 4).

5. Adjust the control for an average box temperature of 25°.

6. What is the cut-in point? ______________________________

7. What is the cut-out point? ______________________________

8. What is the differential? ______________________________

INSTALLING AND ADJUSTING A LOW-PRESSURE MOTOR CONTROL

OBJECTIVE

To be able to:

- Install a low-pressure motor control.
- Adjust a low-pressure motor control.

SECTION I

INSTRUCTIONS:

1. Using the incomplete wiring diagram in figure 5, wire a low-pressure motor control motor control into the electrical circuit, complete the diagram by drawing in the connecting wires.
2. Have the instructor check your work before proceeding.

Checked by ____________________________

Instructor

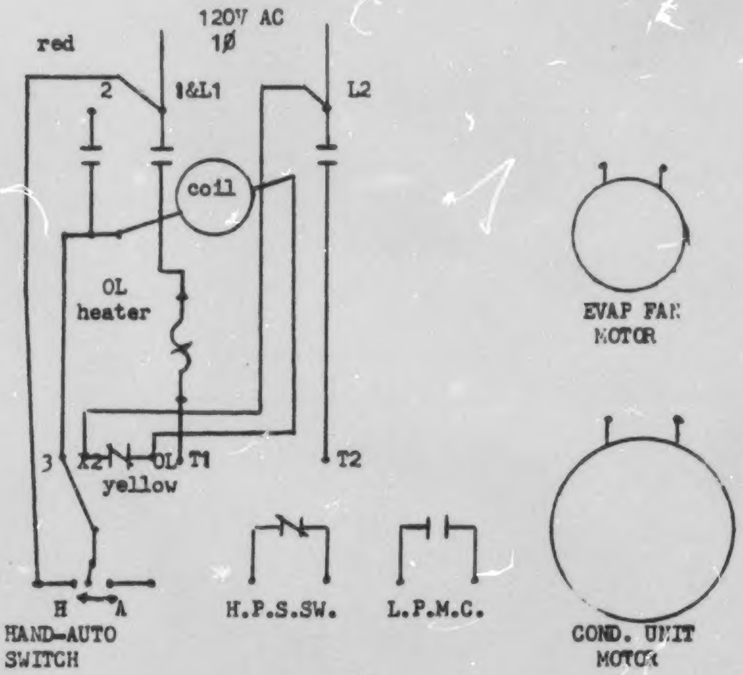
120V AC
1Ø
red
2
1&L1
L2
coil
OL
heater
3
X2
OL
T1
T2
yellow
H
A
HAND-AUTO
SWITCH
H.P.S.SW.
L.P.M.C.
EVAP FAN
MOTOR
COND. UNIT
MOTOR

Figure 5. Low-Pressure Motor Control Wired through Holding Coil

SECTION II

INSTALLING A LOW-PRESSURE MOTOR CONTROL

INSTRUCTIONS

1. Install a low-pressure motor control on the controls and accessories trainer as required.

   CAUTION: When installing a motor control, observe the following precautions.

   - Avoid sharp bends or kinks in the capillary tube.
   - Insure the control is large enough to handle the required electrical load.
   - Make sure that the pressure range of the control is capable of handling the type of refrigerant in the system.
   - Coil excess capillary to avoid vibration.

2. CAUTION: Insure that trainer is disconnected from power source.

3. Then remove control cover and wire in series.

4. Replace control cover.

PROCEDURE

Accomplish all preoperational and operational safety checks listed in WB 3ABR54530-IV-1-P1 prior to operation of the trainer, and observe the listed procedures closely during all operations.

OPERATION

1. Remove the control knob and lock plate assembly as required (see figure 6).

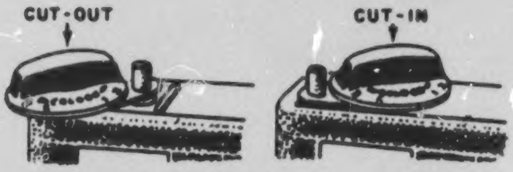

Figure 6. Control Knob and Lock Plate Set for Cut-In and Cut-Out

CAUTION: Do not pry the lock plate off with a screwdriver.

2. Adjust the cut-in for a box temperature of 40°F. What is the cut-in pressure?

   ____

3. Adjust the cut-out for a box temperature of 30°F. What is the cut-out pressure?

   ____

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4. Observe suction pressure gauge during cut-in and cut-out. Are the suction pressure settings the same as control settings? ______________________

   Why? ____

   ____

5. Readjust motor control if required.

6. Have the instructor check your work.

   Checked by ______________________
   Instructor

7. Repeat operation, using different temperature ranges, as often as time permits.

POSTOPERATIONAL SHUTDOWN

1. Place all switches in the OFF position.
2. Unplug the trainer electric cable from wall outlet.
3. Roll up electric cable and place it inside the trainer cabinet.
4. Backseat service valves.
5. Remove manifold gauge assembly.
6. Clean trainer by removing tools and materials and wiping down trainer and floor area.
7. Leave evaporator door open.

INSTALLING AND ADJUSTING A HIGH-PRESSURE SAFETY SWITCH

OBJECTIVE

- Install a high-pressure safety switch.
- Adjust a high-pressure safety switch.

INSTALLATION, IF REQUIRED

1. Mount the control on the trainer.
2. Install capillary tube to discharge side of the unit.

CAUTION: Do not kink or break the capillary tube.

Make sure power is disconnected to the trainer.

3. Wire the control in series in the control circuit of the line starter.
4. Have the instructor check your work before proceeding.

Checked by__________________________
Instructor

ADJUSTMENT

1. Determine normal operating pressure:

   Ambient temperature plus (+) 30°F for forced air condenser, convert to pressure for the type of refrigerant.

2. Adjust cut-out (right-hand adjusting screw) at 20% above normal operating pressure.
3. Adjust cut-in (left-hand adjusting screw) at normal operating pressure.

NOTE: Some high-pressure safety switches have the cut-in adjust because they are manually reset.

PROCEDURE

Accomplish all preoperational and operational safety check listed in WB 3ABR54530-IV-1-P1 prior to operation of the trainer and observe the listed procedures closely during all operations.

OPERATION

1. What is the head pressure? ______________________________

2. What should the head pressure be at this time? ____________________

3. Should this unit be operating? ______________________________

   Why? ____

4. What will happen if the head pressure raised to 20 percent above normal operating pressure? ____________________

5. Have the instructor check your work.

Checked by: ____________________
Instructor

POSTOPERATIONAL SHUTDOWN

1. Place all switches in the OFF position.

2. Unplug the trainer electric cable from wall outlet.

3. Roll up electric cable and place it inside the trainer cabinet.

4. Backseat service valves.

5. Remove manifold gauge assembly.

6. Clean trainer by removing tools and materials and wiping down trainer and floor area.

7. Leave evaporator door open.

REMOVING AND INSTALLING HEAT EXCHANGERS

OBJECTIVE

To be able to:

- Remove a heat exchanger.
- Inspect a heat exchanger.
- Install a heat exchanger.

PROCEDURE

The following is for discussion purposes only.

OPERATION

REMOVAL PROCEDURE

1. Set the motor starter H. O. A. switch to the HAND position.

   NOTE: When performing maintenance in the field on equipment using a low-pressure motor control, it may be necessary to set the cut-out point to 1 p.s.i. or jump the contacts.

2. Close king valve and pump down system.
3. Front seat the suction service valve. Why is this step necessary? __________

   ____

   ____

4. Disconnect liquid line at the inlet and outlet of the heat exchanger.

   CAUTION: Use an open end wrench to hold the heat exchanger when loosening and tightening the flare nuts.

5. Disconnect the suction line at the inlet and outlet of the heat exchanger.
6. Remove the heat exchanger hold-down clamps.
7. Remove the heat exchanger.

INSPECTION PROCEDURE

1. Visually inspect the heat exchanger for damage, cleanliness, and restrictions.
2. Clean if necessary, using an Air Force-approved solvent.

Were there any discrepancies noted? ____________________

Why? ____________________

____

INSTALLATION PROCEDURE

1. Use the hold-down clamps and fasten the heat exchanger to the trainer.

   NOTE: Heat exchangers are normally installed inside the refrigerated space and as near the evaporator as possible.

   Why? ____________________

2. Connect the liquid line to the inlet and outlet of the heat exchanger.

   CAUTION: Be sure the direction of flow is correct.

   NOTE: The hot liquid should normally flow in the outside chamber, figure 7, of the heat exchanger.

   Why? ____________________

   ____

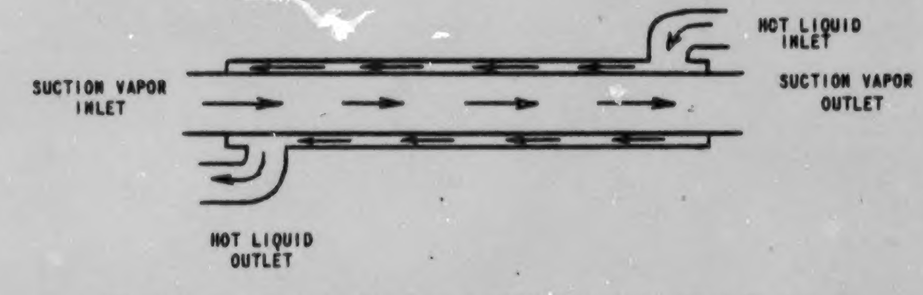

Figure 7. Counterflow in a Shell and Tube Heat Exchanger

3. Connect the suction lines to the inlet and outlet of the heat exchanger.

   NOTE: The liquid and vapor must have a counterflow action (figure 7) through the heat exchanger.

   Why? ____________________

   ____

4. Open the receiver king valve and release a small amount of refrigerant.

5. Check for leaks and repair if necessary.

6. As soon as leaks are repaired, open the king valve and allow pressure to build up.

7. Loosen the flare nut at the suction service valve and purge lines.

8. Open suction service valve to gauge position.

9. Place the motor starter H. O. A. switch in AUTO position.

NOTE: For field maintenance, reset the cut-out on the low-pressure motor control, or remove jumper wires.

10. Check for proper system operation.

11. Charge system if necessary.

12. What is the purpose of the heat exchanger? ______________________

____

13. Explain "flash gas." ______________________

____

14. Why is some "flash gas" necessary? ______________________

____

15. Have the instructor check your work.

Checked by ______________________
Instructor

REMOVING AND INSTALLING AN OIL SEPARATOR

OBJECTIVE

To be able to:

- Charge an oil separator.
- Install an oil separator.
- Check an oil separator for proper operation.
- Remove an oil separator.

PROCEDURE

The following is for discussion purposes only.

OPERATION

CHARGING PROCEDURE

1. Using the manifold gauge assembly, connect a refrigerant drum to the 1/4" male flare fitting on the oil separator oil return port.
2. Charge oil return port to approximately 5-10 p.s.i.
3. Charge oil separator through inlet port with correct refrigerant oil.
4. Stop adding oil as soon as refrigerant pressure is relieved.
    a. What does the pressure release indicate? ______________________________

    ____

    b. Why does the pressure release occur? ______________________________

    ____

    c. Why must an oil separator be charged prior to installation? ______________

    ____
5. Disconnect manifold gauge assembly from oil separator.

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INSTALLATION PROCEDURE

1. Operate the unit and pump system down 1-5 p.s.i.

   NOTE: If system is controlled by a low-pressure motor control, set cut-out 1-5 p.s.i.

   a. What is the position of the suction service valve during the pump-down procedure? ______________________________

   b. Why? ______________________________

   CAUTION: Unit should be shut down now.

2. After pump-down procedure is completed, close condenser inlet valve. Why is this step necessary? ______________________________

3. Front seat the discharge service valve. Why is this step necessary? ______________________________

4. Fabricate and install a line between the inlet port on the oil separator and the discharge service valve.

5. Fabricate and install a line between the inlet port on the oil separator and the condenser.

6. Fabricate and install an oil return line between the oil outlet port and the compressor oil return port.

7. Open the condenser inlet valve momentarily.

8. Check for and repair all leaks.

9. Purge the oil separator and the newly installed lines.

10. Explain the best method of completing Step 8. ______________________________

OPERATION

1. Open the condenser inlet valve.
2. If a low-pressure motor control is used, reset cut-out point.
3. Place compressor service valves in gage position.
4. Put system in normal operation.

REMOVAL PROCEDURES

1. Pump down the low side of the compressor. Is it necessary to pump down the complete low side of system to accomplish step 1? ______________________________
2. Stop the unit.
3. Close the condenser inlet valve.
4. Front seat the discharge service valve.
5. Remove the line from the discharge service valve to the separator inlet port.
6. Remove and destroy all the other lines that were installed.

   CAUTION: Replace the crankcase oil plug immediately.
7. Cap all ports on the oil separator
8. Fabricate and install a discharge line between the discharge service valve and the condenser inlet valve.

[illegible] Open the condenser inlet valve momentarily.

10. Check for leaks.
11. Repair leaks.
12. Purge.
13. Place compressor service valves in gage position.
14. Open the condenser inlet valve. What would happen if the compressor is operated with the condenser inlet valve closed? ______________________________

    ____

15. Place the unit in normal operation.
16. Operate the unit and observe for possible malfunction.
17. Have the instructor check your work.

Checked by ______________________________
Instructor

CONNECTING A SYSTEM

1. Study the arrangement of the components in figure 8.
2. Place the name of each item in the space provided.
3. Draw all necessary lines to complete a simple refrigeration system.
4. Using colored pencils, color code the system using the standard color coding that applies to refrigeration.
5. Have the instructor check your work.

Checked by ______________________________
Instructor

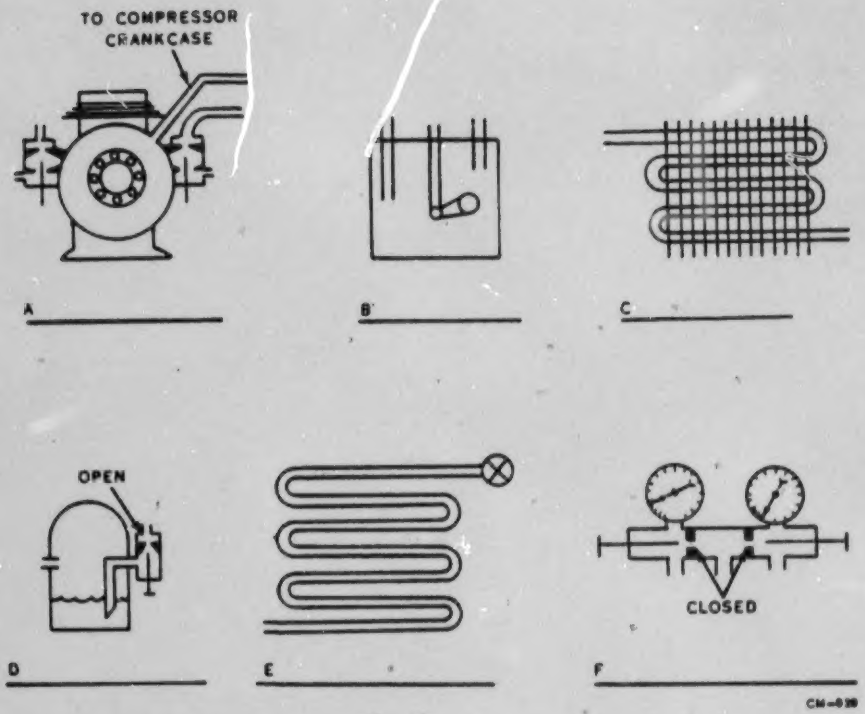
TO COMPRESSOR
CRANKCASE
A
B
C
OPEN
D
E
CLOSED
F

Figure 8. System Components

REMOVAL AND INSTALLATION OF DRIERS

OBJECTIVE

To be able to:

- Remove a drier.
- Install a drier.

PROCEDURE

Accomplish all preoperational and operational safety checks listed in WB 3ABR54530-IV-1-P1 prior to operation of the trainer and observe the listed procedures closely during all operations. If drier does not require replacement, omit steps 4 and 5 under removal procedures.

REMOVAL PROCEDURE

1. Install the manifold gage assembly.
2. Pump down the system.

   NOTE: If the unit is controlled by a low-pressure motor control, adjust the cut-out at 1 p.s.i.

3. Stop the unit.
4. Remove the drier from the liquid line.
5. Plug the lines that are open.

INSTALLATION

1. Connect the drier in the liquid line.
2. Charge for leak test.
3. Test for leaks. Repair if necessary.
4. Purge the part of the system that has been exposed to the atmosphere.
5. What type drier is used in this system? ______________________________
6. What type desiccant is used? ______________________________
7. What is the purpose of a drier in the system? ______________________________

   ____

   ____

8. Operate the system and check for proper operation.

9. Have the instructor check your work.

Checked by ____________________
Instructor

POSTOPERATIONAL SHUTDOWN

1. Place all switches in the OFF position.
2. Unplug the trainer electrical cable from the wall outlet.
3. Roll up electrical cable and place it in the trainer cabinet.
4. Backseat service valves.
5. Remove manifold gauge assembly.
6. Clean trainer by removing tools and material and wiping down trainer and floor area around trainer.
7. Leave trainer evaporator door open.

USING TROUBLE ANALYSIS CHARTS

OBJECTIVE

To be able to use the trouble analysis chart and locate troubles on different systems.

NOTE: Study the following charts. With the use of the Trouble Analysis Charts in SG 3ABR54530-IV-4, fill in the information in the blank columns.

PROCEDURE

Accomplish all preoperational and operational safety checks listed in WB 3ABR54530-IV-1-P1 prior to operation of the trainer, and observe the listed procedures closely during all operations.

COMPLAINT: Unit will not operate.

TYPE OF SYSTEM: Any with pressure motor control

Observations	Trouble	Remedy
Suction pressure: Below normal cut-in point Head pressure: Below normal		

COMPLAINT: Unit too noisy **TYPE OF SYSTEM:** Any

Observations	Trouble	Remedy
Compressor is noisy		

Checked by ________________________

Checked

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LOCATING AND REMOVING RESTRICTIONS

OBJECTIVE

To be able to locate, identify, and remove restrictions in refrigeration systems.

1. Operate the system.
2. Record the pressures:

   Low side ____________________________________

   High side ____________________________________
3. Run your hand over the entire length of the liquid line.
4. A restriction is indicated by ______________________________.
5. Tape a thermometer to the liquid line on each side of the restriction and record the temperatures:

   Inlet side ____________________________________

   Outlet side ____________________________________
6. Pump down the unit.
7. Remove the restriction.
8. Clean the screen or fabricate and install a new line as required.
9. Place the trainer back in operation.
10. Have the instructor check your work.

Checked by ____________________________
Instructor

11. Repeat this project as often as time permits.

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TROUBLE ANALYSIS PROCEDURES

OBJECTIVE

To be able to:

- Determine motor control trouble.
- Locate motor control trouble.
- Eliminate motor control trouble.
- Analyze refrigerant control troubles.

SECTION I

MOTOR CONTROL TROUBLES

COMPLAINT

Motor will not function.

NOTE: In locating the cause of this complaint, the serviceman should determine first whether electrical or mechanical failure has stopped the machine.

OBSERVATION

1. Motor and compressor are free to rotate.
2. Source of power and fuse are satisfactory.
3. Thermal protector switch set.

CHECKING PROCEDURE

1. Install manifold gage assembly.
2. Check the high side pressure.

   Why is this necessary? ______________________________

   ____
3. Break the circuit at the fuse box.
4. Install a jumper wire around the motor control.

   NOTE: This wire must be insulated and large enough to carry the required electrical load.
5. Momentarily complete the electrical circuit to the motor (no more than 5 seconds).

If the motor runs, the trouble is ______________________________.

6. Check out the motor control and replace if necessary.

7. If replacement is required, adjustments must be made as directed by the instructor.

8. After the trouble is repaired, operate the system.

9. Observe the unit for correct operation.

SECTION II

BOX TOO COLD

COMPLAINT

Milk, eggs, and vegetables are freezing during short term storage.

OBSERVATION

1. Condensing unit has a long "running" time and short "off" time.
2. Motor control range adjustment set at the warmest position.

CHECKING PROCEDURE

1. Inspect the motor control power element.

   NOTE: On domestic refrigerators, the power element bulb must make complete contact with the evaporator.

2. Install the manifold gage assembly.
3. Operate the system.
4. Observe the low and high side pressures.

   Are these pressures normal? Low side ______________ High side ______________

5. Check the low side pressure at "cut-out" and "cut-in" points.

   Are these pressures normal? "Cut-Out" ______________ "Cut-In" ______________

6. Check the box temperatures at "cut-in" and "cut-out."
7. Readjust the control as necessary.
8. Check the system for correct operation.
9. What is the abnormal function of the motor control power element leaks?

   ____

SECTION III

REFRIGERANT CONTROL TROUBLES

1. Install the manifold gage assembly.
2. Operate the unit.
3. Observe the low and high pressure.
4. Record the high side pressure. ______________________________
5. Record the low side pressure. ______________________________
6. Are these pressures normal? High side __________ Low side __________
7. Observe the evaporator.
8. Record the operating conditions of the evaporator. ______________________________

    ____

    ____
9. What type of motor control is being used? ______________________________
10. Could the motor control cause this malfunction? ______________________________
11. Observe the sight glass.
12. List two things that might cause bubbles in the sight glass.

    a. ____

    b. ____
13. Observe the refrigerant control.
14. Record the operating conditions of the refrigerant control. ____________________

    ____

    ____
15. A "hissing" sound at the refrigerant control is an indication of ____________________

    ____

    ____

    ____

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16. What is the malfunction in this system? ______________________________

____

____

17. List several other refrigerant control troubles.

    a. ____

    b. ____

    c. ____

    d. ____

18 Repair the malfunction.

19. Return the system to normal operation.

20. Ask the instructor to check your work.

Checked by ______________________________
Instructor

USING THE TROUBLE ANALYSIS CHART

OBSERVATIONS	TROUBLE	REMEDY
1.	1.	1.
2.	2.	2.

OBSERVATIONS	TROUBLE	REMEDY
3.	3.	3.
4.	4.	4.
5.	5.	5.

Have the instructor check your work.

Checked by:______________________
Instructor

POSTOPERATIONAL SHUTDOWN

1. Place all switches in the OFF position.
2. Unplug the trainer electrical cable from the wall outlet.
3. Roll up electrical cable and place it in the trainer cabinet.
4. Backseat service valves.
5. Remove manifold gauge assembly.
6. Clean trainer by removing tools and material and wiping down trainer and floor area around trainer.
7. Leave trainer evaporator door open.

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
V	Domestic and Commercial Refrigeration

1 COURSE CONTENT	2 TIME
1. Domestic Units	46 (36/10) Days 36 thru 41
a. Using workbook, identify all components and construction features of the domestic refrigerator trainer, as to their type and purpose. STS: 13a(1)(d), 13b(1), 13d(1), 17a(1), 17a(3) Meas. W	(9/3) Days 36 and 37
(1) Major components of a domestic refrigerator	
(2) Temperature and construction features of a domestic refrigerator	
(3) Types of domestic refrigerators	
(4) Purpose of a domestic refrigerator	
b. Using the schematic of the electric defrost system, complete the workbook project by identifying all malfunctions and maintenance required. STS: 10e(2)(d), 10e(6), 17d. Meas: W, PC	(3/1) Day 37
(1) Common malfunctions of the electric defrost system	
(2) Required maintenance for electric defrost system	
c. Using tools provided, remove, replace and leak check a capillary tube using the domestic refrigeration trainer and observing all workbook requirements. 15b(2), 15b(3), 15b(4), 17c(1), 17c(3) Meas: W, PC	(3/1) Day 38
(1) Proper tools for removing and replacing a capillary tube	
(2) Procedure of troubleshooting, removing, replacing, and leak checking a capillary tube	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3ABR54530	16 January 1976	45

d. Using tools provided, leak check, evacuate and charge a domestic refrigeration trainer to the specifications outlined in the workbook. STS: 14f, 14j, 14k, 17c(2) Meas: W, PC	(9/3) Days 38 and 39

(1) Purpose and type of access valves

(2) Types of leak detectors

(3) Procedures for evacuating the refrigeration system

(4) Procedures for the weighted method of charging a domestic refrigeration

(5) Procedures for direct charging a domestic refrigerator

e. Using test instruments and schematics of current, time delay and potential start relays, correctly check the flow of current thru each relay and complete entries in workbook. STS: 10e(6), 10f(3), 21b(1), 21b(2) Meas: W, PC	(6/0) Day 40

(1) Types of current relays

(2) Types of time delay relays

(3) Types of potential relays

(4) Start capacitors

(5) Run capacitors

f. Using multimeter, determine the run, start and common terminals of a hermetic compressor, observing the workbook requirements. STS: 10f(4), 10g(1), 10g(2), 21b (3). Meas: W, PC	(1.5/.5) Day 41

(1) Terminal arrangement and identification

(2) Thermal overloads

g. Using an amprobe, push button start cord and jumper wire, check a hermetic compressor for proper operation in accordance with the specifications outlined in workbook. STS: 10g(1), 10g(2), 21b(3) Meas: W, PC	(2 /.5) Day 41

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

(1) Operation of the push button test cord

(2) Operation of the jumper cord

(3) Use of the amprobe

h. Using the motor start analyzer, check the hermetic compressor for internal grounds and opens, following procedures in the workbook. STS: 10f(5), 13a(3), 13a(5), 17c(1) Meas: W, PC — (2.5/1) Day 41

(1) Operation and uses of the motor start analyzer

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SG3ABR54530-V-1, Domestic Units

WB 3ABR54530-V-1-P1,	Familiarization and Operation of Domestic Refrigerators
WB 3ABR54530-V-1-P2,	Troubleshooting Electric Defrost
WB 3ABR54530-V-1-P3,	Install a Capillary Tube
WB 3ABR54530-V-1-P4,	Charging a Hermetic Unit
WB 3ABR54530-V-1-P5,	Wiring Starting Relay Circuit
WB 3ABR54530-V-1-P6,	Determining Terminal Arrangement
WB 3ABR54530-V-1-P7,	Troubleshooting Hermetic Units
WB 3ABR54530-V-1-P8,	Using Motor Start Analyzer

Audio Visual Aids

Charts, Set, Domestic Units

Transparencies, Set, Domestic Refrigeration

Training Film: TF 6038a, Compressors, Hermetic and Semihermetic-Electrical

Training Film: TF 6038b, Compressors, Hermetic and Semihermetic - Starting Relay Circuits

Training Equipment
Trainer, Current Relay (12)
Trainer, Potential Relay (12)
Trainer, Refrigeration Compressor (12)
Trainer, Hermetic Seal Refrigeration Compressor (12)
Trainer, Terminal Identification (2)
Multimeter (2)
Multimeter, Amprobe/Voltmeter (3)
Special Equipment: Electronic Leak Detector (4), Charging Station (2), Motor Start Analyzer (2), Soldering Equipment (6), Pushbutton Test Cord (2), Hermetic Compressors (2), and Domestic Refrigerator (2)

Training Methods
Discussion/Demonstration (18.75 hrs)
Training Film (0.75 hr)
Performance (16.50 hrs)
CTT Assignment (10 hrs)

Multiple Instructor Requirements
Safety, Supervision (2)

Instructional Guidance
Explain how electrical hazards may be overcome if proper safety procedures are practiced on equipment. Have the students work in teams (buddy system) on energized circuits. Outside Assignment: Day 36, direct students to review WBs V-1-P1 and P2; Day 37, P3 and P4; Day 38, P5; Day 39, P6; Day 41, P7 and P8.

MIR: Two instructors are required for 14 hours during student performance (3.25 hours in Day 38, 5 hours in Day 39, 3 hours in Day 40, and 2.75 hours in Day 41).

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	Refrigeration and Air Conditioning Specialist
BLOCK NUMBER V	BLOCK TITLE Domestic and Commercial Refrigeration

1 COURSE CONTENT	2 TIME
2. Commercial Units	30 (22/8) Days 42 thru 45
a. Using electrical diagram and test equipment provided by instructor, operate and troubleshoot a walk-in refrigerator and automatic defrost system to determine the operating condition. STS: 10e(2)(d), 10e(6), 10g(1), 10g(2), 17a(8), 17a(9), 17d, 21f. Meas: W, PC	(6/2) Day 42
(1) Types of walk-ins	
(2) Major components	
(3) Insulation materials	
(4) Different types of defrost systems	
(5) Different types of defrost timers	
(6) Typical wiring diagram of a walk-in freezer with electrical defrost	
(7) Troubleshooting a walk-in box	
b. Using tools provided operate and adjust a water cooler trainer to maintain water at 50 to 55° F. STS: 14f, 17a(2), 17c(4). Meas: W, PC	(3/1) Day 43
(1) Types and kinds of units	
(2) Major components	
(3) Construction features	
(4) Common troubles	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
3ABR54530	16 January 1976	49

ATC FORM OCT 75 133 PREVIOUS EDITION IS OBSOLETE

COURSE CONTENT

c. Using the following trainers: reach-in box, display case and ice cream cabinet complete the workbook project by correctly identifying major components and tracing refrigerant and air flow of each unit. STS: 14f, 17a(4), 17a(5), 17a(6) Meas: W, PC

(3/1)
Day 43

(1) Types of units

(2) Major components

(3) Construction features

d. Using workbook, list the correct installation, preoperational, adjustment and maintenance procedures for commercial refrigeration units. STS: 14d, 14f, 17b, 17c(1), 17c(4), 17c(5), 21a. Meas: W, PC

(4/1)
Day 44

(1) Installation procedures

(2) Preoperational checks

(3) Operational checks

(4) Adjusting controls

(5) Using blueprints and drawing

e. Using the ice maker trainer, complete the workbook project by correctly identifying components, principles of operation and required maintenance. STS: 14f, 17a(7) Meas: W, PC

(6/3)
Day 44
and 45

(1) Types of ice makers

(2) Construction features

(3) Major components

(4) Cleaning procedures

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-V-2, Commercial Units
WB 3ABR54530-V-2-P1, Maintenance and Troubleshooting Walk-In Boxes
WB 3ABR54530-V-2-P2, Walk-In Freezer Electrical System
WB 3ABR54530-V-2-P3, Water Cooler Maintenance
WB 3ABR54530-V-2-P4, Repair and Maintenance of Reach-In Boxes, Display Cases and Ice Cream Cabinets
WB 3ABR54530-V-2-P5, Installation of Commercial Units
WB 3ABR54530-V-2-P6, Adjusting Motor Controls on Commercial Refrigeration Units
WB 3ABR54530-V-2-P7, Familiarization and Operation of Ice Makers

Audio Visual Aids
Charts, Set, Commercial Units
Transparencies, Set, Commercial Refrigeration

Training Equipment
Trainer, Walk-In Refrigerator (6)
Trainer, Cutaway Water Cooler (12)
Trainer, Water Cooler (4)
Trainer, Display Case (12)
Trainer, Reach-In Refrigerator (12)
Trainer, Ice Cream Cabinet (12)
Trainer, Ice Maker (12)
Trainer, Water Dispenser (12)

Training Methods
Discussion/Demonstration (11 hrs)
Performance (11 hrs)
CTT Assignment (8 hrs)

Multiple Instructor Requirement
Safety, Equipment, Supervision (2)

Instructional Guidance
Electrical safety should be emphasized for energized circuits.
Outside Assignment: Day 42, direct students to review V-2-P1 and P2; Day 43, P3 and P4; Day 44, P5 and P6; Day 45, P7.

MIR: Two instructors are required for 3 hours during student performance in Day 42.

4. Related Training (identified in course chart) (2)

·22

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

4. Measurement Test and Test Critique

2
(2/0)
Day 45

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STUDY GUIDE 3ABR54530-V-1

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

DOMESTIC UNITS

January 1975

SHEPPARD AIR FORCE BASE

11-7

Designed For ATC Course Use

DO NOT USE ON THE JOB

234

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54530-V-1
21 January 1975

DOMESTIC UNITS

OBJECTIVE

To help you to learn the various types, purpose, and construction features of hermetically sealed refrigeration systems, and to:

- Identify the major components of hermetically sealed units
- Install, operate, check, and service hermetic units
- Install a capillary tube refrigerant control
- Use special tools and equipment to charge a hermetically sealed unit that has a capillary tube refrigerant control
- Wire and troubleshoot starting relays and relay circuits
- Determine the correct terminals on a hermetic compressor
- Use the motor-start analyzer to check, troubleshoot, and start hermetic compressors

INTRODUCTION

The definition given in the dictionary for the word hermetic is "to be made airtight so that no gas can enter or escape."

The Air-Conditioning and Refrigerating Data Book's definition of a hermetically sealed unit is, "A sealed (hermetic type) condensing unit is a mechanical condensing unit in which the compressor and compressor motor are enclosed in the same housing with no external shaft or shaft seal, the compressor motor operating in the refrigerant atmosphere.

"The compressor and compressor motor housing may be of either the fully-welded or brazed type, or of the serviced-sealed type. In the fully-welded or brazed type, the housing is permanently sealed and is not provided with means of access for servicing internal parts in the field. In the service-sealed type, the housing is provided with some means of access for servicing internal parts in the field."

Generally speaking, hermetic units include refrigeration systems that use a hermetic compressor and a capillary tube refrigerant control.

Due to the ease of manufacture, simplicity, economical cost, and relatively troublefree operation, a large number of refrigeration systems are being built as hermetically sealed units. These include domestic refrigerators (household boxes), cold storage boxes (freezers), water coolers, window air conditioners, ice cream cabinets, and beverage coolers.

This supersedes SG 3ABR54530-V-1 and WB 3ABR54530-V-1-P1 thru P8, 1 Oct 1973
Copies of the superseded publication may be used until the supply is exhausted.

Since most people are more or less familiar with the common household refrigerator, it will be used in the instruction of hermetically sealed refrigeration units.

DOMESTIC REFRIGERATORS

The term "domestic refrigerator" includes all types of refrigerated boxes normally used in the kitchen. It includes refrigerator-cold storage box combinations, but does not include separate cold storage boxes.

A domestic refrigerator is normally an upright box with one or two doors. It may be either free standing or built into a wall. A modern domestic refrigerator is a self-contained unit as shown in figure 1. It can be placed in operation by removing the shipping bolts (if they have them), connecting the power source and adjusting the motor control.

Most domestic refrigerators have at least three different temperature compartments: a freezing compartment for freezing ice cubes and storing frozen foods, a medium temperature area for foods and beverages, and a high temperature, high humidity compartment for fresh vegetables and fruits. They may have such accessories as a butter conditioner, egg shelves, beverage containers and storage shelves in the door.

Construction Features

The outer shell is normally made of several pieces of sheet metal welded together and covered with appliance enamel. The inner shell is usually formed from one piece of metal. It may be either porcelain or enamel finished. The space between the two sheets is filled with insulating material. .

INSULATION. Any substance that will retard the flow of heat may be used for insulating purposes. A great number of substances have been used for insulation in domestic boxes. Fiberglas and foamed plastic are the most widely used in domestic refrigerators.

Fiberglas. This is one of the most widely used insulating materials. It is made from silicon dioxide (glass sand) and is expanded with refrigerant or carbon dioxide. When used in domestic refrigerators, it is made in the form of mats and is approximately three inches thick. If it is necessary to handle Fiberglas, wear a long sleeved shirt and rubber gloves as the particles of glass will penetrate the skin and cause a burning, itching condition.

Foamed Plastic. This is a relatively new insulating material. It is manufactured from plastic that has been foamed or expanded by the use of refrigerant, carbon dioxide or some other highly volatile agent. Foamed plastic is more expensive than Fiberglas, but you only have to use half as much of it to get the same insulating effect. Foamed plastic is light in weight, easily worked and may be manufactured in various forms and shapes. Therefore, it makes a very desirable insulating material and is used in the so-called "thin-walled" boxes.

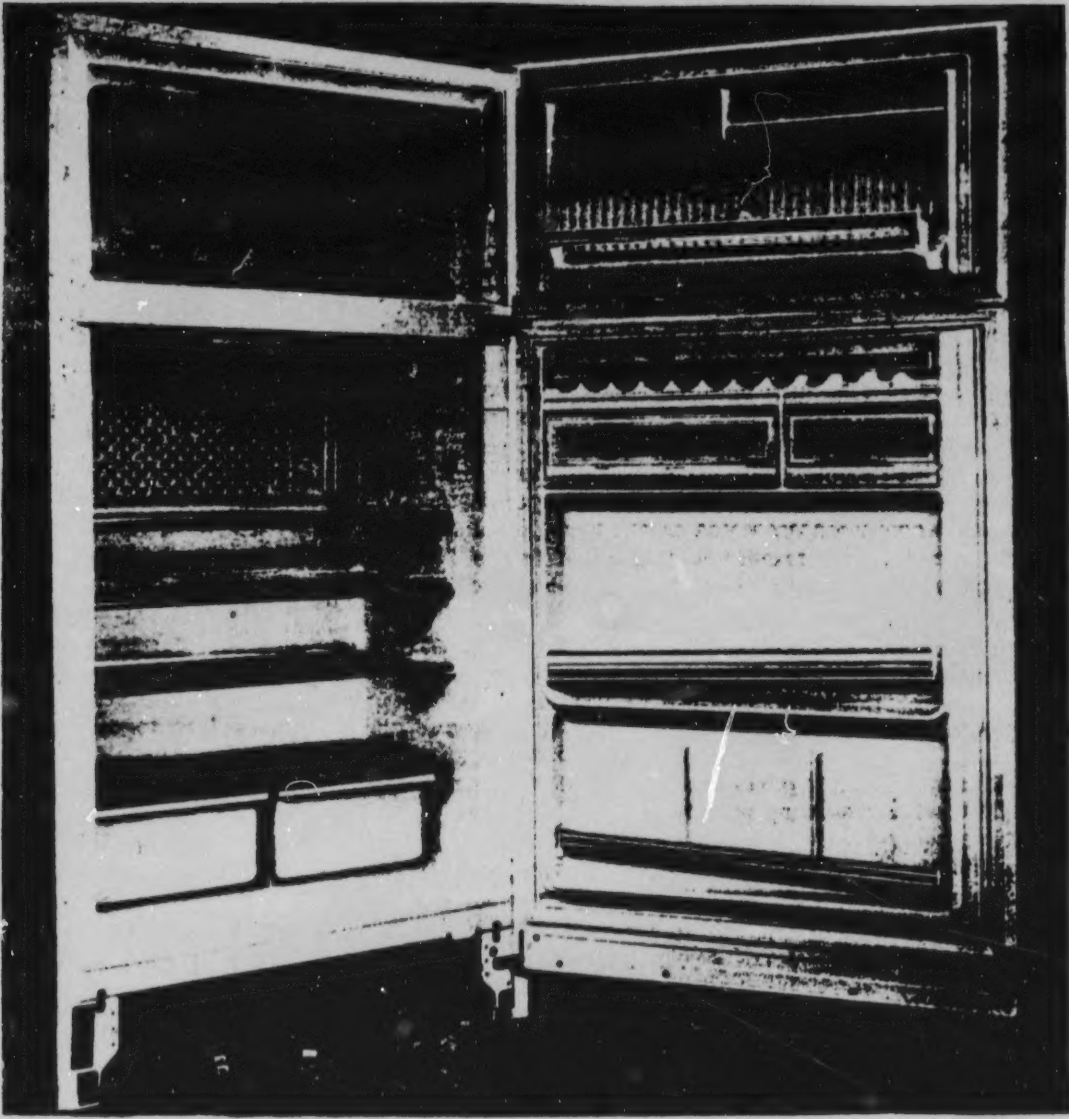


Figure 1. Domestic Refrigerator

VAPOR BARRIER. Condensation of moisture will occur on any surface that is at a temperature below the dewpoint of the surrounding air. Therefore, we must keep moisture out of the insulated space between the inner and outer shell. This is particularly important around the freezing section. Several substances are used for this purpose, but the most important one in domestic boxes is plastic. The plastic is placed in such a way as to stop the water vapor in the air from getting to the cold surface. The suction line is often insulated with a rubber-like substance known as insulation tape. The holes where the refrigerant or electrical lines go through the box are usually stuffed full of a soft putty-like substance known as permagum cords. An odorless tar is often spread over an area or surface to prevent vapor transmission.

DOOR. The modern refrigerator may have either one or two doors. These doors are designed to cover the entire front of the refrigerator. The inside of the door may be recessed for small shelves or a butter conditioner. The inside panel is made of plastic. Since the panel is light it aids in reducing the total weight of the door. The plastic panel is designed to aid in keeping the door from warping.

BREAKER STRIP. The breaker strips, see figure 2, are pieces that cover the space between the inner and outer shells. Each manufacturer installs the breaker strips in a different manner. Some use screws, some use clamps, while others snap them in.

Breaker strips are made of plastic. When the strips are cold, they become brittle and will break very easily. Before attempting to remove a cold breaker strip, run a towel dipped in warm water over it. Before installing a cold breaker strip, dip it in warm (not hot) water. This will make it soft and pliable and will reduce the possibility of breakage.

MULLION HEATER. The mullion heater is a strand of high resistance wire attached to a strip of aluminum foil. The mullion heater is installed around the doors under the breaker strips. When the box is plugged in, electricity is applied to the mullion heater which gets warm and adds enough heat to the area around the door to reduce sweating or freezing. A mullion heater is particularly important around the door of the freezer. If the mullion heater fails, moisture will condense around the door and the door will freeze shut.

Major Components

Domestic refrigerators use the same basic components as any other refrigeration system; a compressor, condenser, refrigerant control, and evaporator. However, each of these units are designed for a particular application and temperature range.

COMPRESSOR. Modern domestic refrigerators use a hermetic compressor. These compressors have some outstanding advantages over open type units. In all instances the compressor-motor assembly is much lighter and somewhat stronger as

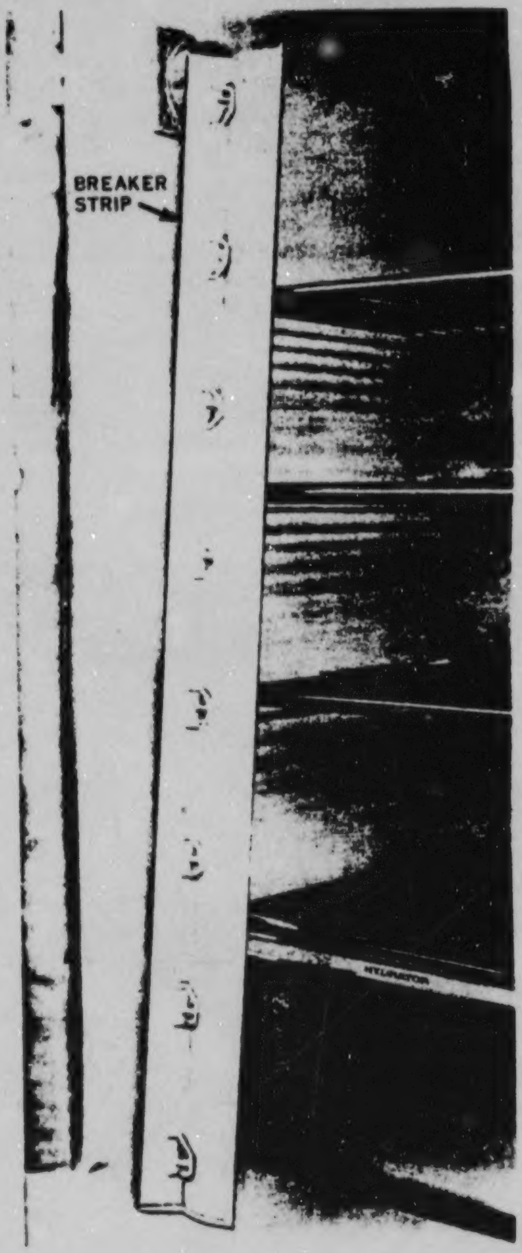


Figure 2.

a unit. Strong foundations for mounting the heavy open type compressors are completely eliminated. The faster operating speeds physically reduce the size of the hermetic compressors. The motor and compressor are connected to the same shaft and are positioned as close together as possible. This feature eliminates the bulkiness of the open style system where the motor and compressor were set apart and driven by V-belts.

The most important advantage of the hermetic unit is that the ever troublesome shaft seal is completely eliminated. The elimination of the shaft seal was the prime reason for the development of the hermetic type compressor.

The hermetic design allows the motor and compressor to be enclosed in a housing that is airtight. Moisture, dust, grease, and all foreign particles are sealed out which allows the assembly to operate free of these disturbing elements. As a result the unit functions at full rated capacity for a longer period of time.

Hermetic type compressors operate more quietly than the open style. Any sound originating in the compressor or motor must first pass through the refrigerant vapor within the housing. It must then be transmitted through the steel casing before it can reach the outer area. As a result, the noise is greatly reduced. Vibrations are almost eliminated due to the rapid cycling of the high-speed unit which tends to smooth out larger pulsations. The complete assembly is usually mounted on springs or rubber shock absorbers that dampens out any vibrations that might originate from the assembly.

As a unit, all of the advantages previously discussed indirectly result in an efficiency that places the hermetic unit superior to other types.

Hermetic units have two main disadvantages. They are not easily serviceable in the field and in case of motor burnout the complete system becomes contaminated.

TYPES AND CLASSIFICATION OF HERMETIC COMPRESSORS

The types of hermetic compressors are: The reciprocating and the rotary. The reciprocating compressor is the most popular compressor for all sizes of hermetic systems. It has more parts therefore costs more to manufacture than the rotary. However, since it is so effective and efficient under large loads, it is used more often than the rotary. The rotary is used in hermetically sealed fractional hp systems only. Hermetic compressors are normally classified under one of the following headings:

- Accessible (semihermetic). These compressors are normally fitted with service valves. They can be serviced in the field to the extent of replacing the valves, valve plates, pistons, rods, and rewinding the motor.

- Sealed (internally shock mounted). Internally shock mounted compressors need very little external shock mounting. A small rubber grommet around the mounting bolt is necessary.

- Sealed (external shock mounted). The compressors must be spring supported or mounted on large mounting pads.

Design Characteristics

Reciprocating hermetic compressors have five major design characteristics. These characteristics and some needed information concerning them are listed below.

SHAFT MOUNTING. The crankshaft is mounted either vertically or horizontally.

SHAFT DESIGN. There are three shaft designs: crank, eccentrics, and the scotch yoke. (The scotch yoke is used only on low torque fractional hp compressors.)

METHOD OF LUBRICATION. Hermetic compressors are lubricated by one of the following methods: splash, flood, or forced feed systems.

The splash system is used almost universally in fractional horsepower units. The bearing clearance must be large so that the oil can enter easily. The large bearing clearances ply the splashing effect of the dippers in the oil causing these compressors to produce a little more noise than the other types. The splashing at high speed encourages oil frothing and pumping. The flooded system includes all types of devices that lift the oil up and allows it to flood (run down) over the bearings, pins, and surface areas. The oil is not agitated as violently as with the splash system which results in quieter operation and less oil pumping. This system is often used in air-conditioning compressors. The forced feed system uses a pump to force the oil through drilled passages to the bearings. The bearings can be closely fitted resulting in very quiet operation. This type system is used on large high-speed compressors.

MOTOR COOLING. The cooler an electric motor operates, the more power it will produce. Therefore, it is imperative that the motor in a hermetic compressor be kept as cool as possible. Hermetic compressors are normally cooled by one or more of the following three methods: suction gas cooling, air cooling, and oil cooling. The suction gas is directed around the motor before it goes to the cylinder. There may be a fan inside the shell that aids in forcing the cold gas around the motor. To prevent oil or liquid refrigerant from entering the suction intake these compressors are designed so that only refrigerant vapor can enter the suction intake due to the fact that suction return vapors must first pass through or around the windings where all the oil and liquid refrigerant will be vaporized. This design is commonly referred to as an antislugging device. Air is used to cool hermetic compressors by both natural and forced convection. Some compressors have external fins that aid in heat transfer. Some domestic refrigerators have a separate oil cooler circuit that cools the oil in the compressor.

SHELL DESIGN. Manufacturers produce hermetic compressors in a variety of shell designs. The mechanics in the field often apply common names to these compressors according to their shape or mounting. These are common names only and may not be familiar to personnel in different geographic areas. The pancake compressor is the only shell design that is accepted industry-wide by both manufacturers and service personnel.

Condensers

The condensers in domestic refrigerators are usually made of steel and are of the following construction types: plate finned (forced convection), coiled tubing with a wire frame, and coiled tubing mounted on the inside of the refrigerator shell. In the last few years, several manufacturers have built the condenser as an integral part of the outside wall. From a visual standpoint, it appears that the unit does not have a condenser. However, let the unit operate for about 30 minutes and then run your hand over the outside of the box. The hot area will indicate the exact location of the condenser. When these units first came out, it was quite difficult to convince some of the users that the outside of their refrigerator was supposed to get hot.

OIL COOLER CIRCUIT

Some compressors used on domestic refrigerators require oil cooling. This is usually accomplished by passing the discharge gas through an oil cooler circuit, desuperheating it, and then returning it to the compressor where it picks up heat from the oil before going to the condenser.

The schematic in figure 3 illustrates the hot gas flow through the oil cooler circuit.

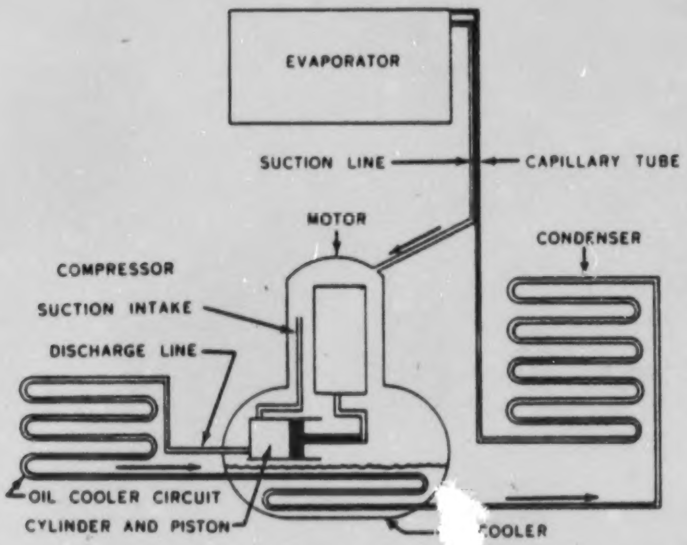


Figure 3. Oil Cooler Circuit

Refrigerant Control

All modern domestic refrigerators use a capillary tube refrigerant control. This type of control is simple, economical, and allows the use of a low starting torque motor. One end of the capillary tube is attached to the bottom of the condenser. You may find a strainer installed between the condenser and capillary tube. The capillary tube is soldered to the suction line to act as a heat exchanger and give the capillary tube added strength and terminates in an expansion chamber at the top of the evaporator.

PRINCIPLE OF OPERATION OF CAPILLARY TUBE. Liquid refrigerant with a pressure of 120 to 140 psi and a temperature of 90 to 120°F enters the capillary tube. (Pressures and temperatures are approximations.) As the liquid travels through the capillary tube, its pressure is reduced by the resistance of the tubing. At the same time, its temperature is being reduced by the cold suction line. These two forces continue to act on the liquid refrigerant as it proceeds through the capillary tube. However, the pressure is reduced (comparatively) faster than the temperature. At some point (usually within the last 1/3 of the tube) the pressure of the liquid refrigerant is reduced below its boiling point. Some of the liquid refrigerant "flashes" or boils. The vapor occupies more space than the liquid so the resistance to flow is increased. The temperature of the refrigerant is decreased by both the flashing of the liquid and by the action of the cold suction line. The point where the flashing first occurs to the end of the capillary tube is known as a "vapor lock or bubble point."

All capillary tubes have a vapor lock. The length of the vapor lock depends on a combination of the following factors:

- Condensing temperature.
- Condensing pressure.
- Amount of subcooling of the liquid in the condenser.
- Temperature of the suction line.
- Pressure difference between the low and high side.
- The length and diameter of the capillary tube.

Thermostat

The thermostat used on normal refrigerators is a factory adjusted item with a set differential of approximately 13 degrees and an adjustable range. At the highest setting, the evaporator temperature may be 10°F and at the lowest setting -20°F.

The thermostat is usually installed in a location convenient to the user with the thermal bulb clamped to the evaporator.

Evaporators that defrost each "off cycle" require a special thermostat. This thermostat has a built-in lockout feature that keeps the compressor off unitl the evaporator warms up to 37°F. This guarantees that the evaporator completely defrosts each "off cycle." When using this type thermostat, you adjust the cutout only. The cut-in remains constant at 37°F.

NOTE: Do not attempt to repair thermostat on domestic boxes. If they are malfunctioning in any way, replace the complete unit.

POSSIBLE TROUBLES. Thermostats are subject to three malfunctions: Points that will not close, points that will not open, and erratic operation.

- Points that will not close is very easy to diagnose and find. The symptoms that indicate this malfunction are, box temperature high, and the unit will not run. Checking procedures, unplug box, loosen the thermostat enough to get to the terminals on back. Put a "jumper wire" across the terminals and plug in the box. If the box runs with the jumper wire installed but does not run when you remove it, the thermostat is faulty and must be replaced.

- Points that do not open will cause the compressor to run all the time and freeze up everything in the refrigerator section. The only remedy is to replace the thermostat. However, if the thermal bulb is not attached securely to the evaporator, it will give the same symptoms as a malfunctioning thermostat.

- Erratic operation is very hard to diagnose and find. A great number of different things can cause erratic operation; intermittent low power, faulty overload or starting relay, intermittent open in electrical wiring, or a bad thermostat. The only thing to do is to check the complete system. If you do not find the trouble, change the thermostat.

REPLACEMENT PROCEDURES. To remove a thermostat, unplug the box and remove the adjustment knob. With the adjustment knob removed, you will see two or three mounting screws. Remove these screws. Take out the thermostat, noting the location of the bellows in relation to the mounting. (This will aid you in installing the new unit.) It may be necessary to turn the thermostat around a bit to get it to come out of the mounting hole. Remove the terminal wires, noting their correct location. They should be replaced the same as they came off. Disconnect the thermal bulb from the evaporator. Tie a strong string to the end of the thermal bulb. Slowly pull the thermostat, capillary tube, and thermal bulb from the box. The string can now be used to pull the new thermal bulb back into place. After connecting the electrical wiring, installing the thermal bulb and mounting the thermostat, the unit can be put back into operation.

Evaporators

The evaporators used in domestic refrigerators must be rugged, functional, and attractive.

Frosting type refrigerators usually use a flooded type evaporator or a plate with aluminum tubing attached to the back. Very often you will find a refrigerator that uses a plate evaporator with a preformed refrigerant coil in the freezer section. These plate type evaporators are normally made of aluminum. Home freezers often use an evaporator that is composed of coiled aluminum tubing crisscrossed with steel or aluminum wire.

Manufacturers do not recommend attempting to repair aluminum evaporators. When an aluminum evaporator gets a hole in it, the manufacturer recommends replacing the complete assembly.

Suction Line

The suction line is usually attached at the top of the evaporator on domestic boxes. There is usually some surplus suction line run along one side or else coiled inside the box. This extra length is to allow the suction gas to pick up enough heat (from the capillary tube) so that the suction line will not sweat outside the box. A sweating suction line usually indicates an overcharge. If the system is correctly charged and the suction line still sweats, it must be insulated to keep the condensate from dripping on the floor. Suction lines are usually made from 5/16 to 3/8 inch copper tubing.

Door Gasket

Domestic refrigerators have a synthetic rubber or flexible plastic gasket around the door. This gasket or seal is designed to make an airtight seal between the door and refrigerator body. Door seals usually last from five to seven years. It is always best to replace door seals with an exact like item. However, this is not always possible. Sometimes you will find it necessary to use a general replacement seal. There are several types of seals in general use. The door should be removed and laid on a flat surface when replacing the gasket, this will prevent warping of the door.

LOCATION OF THE REFRIGERATOR

The convenience of the work area normally determines the location of the refrigerator. However, the following factors must be given some consideration. Do not expose to direct sunlight. The solar heat gain will increase the cost of operation. Near a power supply, extension cords are unauthorized in the Air Force as they reduce the line voltage. Ventilation is required for satisfactory operation as there must be an unrestricted flow of air through the condenser. Temperature is another factor. If the ambient is excessively high, the condensing unit will have a long on-cycle and a short off-cycle. This reduces efficiency and increases the cost of operation. If the ambient air is too cold, the head pressure will fall below allowable limits, and the unit will not operate satisfactorily.

CLEANING. Cleaning the inside of the box is the primary responsibility of the user. However, this does not relieve the refrigeration specialist from having to perform the job occasionally. One of the best cleaning agents is baking soda, water, and a soft rag. Sometimes it may be necessary to use warm soapy water. Any of the standard household detergents will work very satisfactorily. The use of abrasives (cleaning powder or steel wool) is not recommended. These agents will remove the luster from the enamel and leave a dull finish. Some stains cannot be removed without the use of an abrasive. So the question becomes, Which would you rather have, a dull finish or a stain?

A plate type condenser can be cleaned with a brush and a vacuum cleaner. Forced convection condensers become clogged with dirt, lint, and other types of foreign material. Sometimes these condensers will become so dirty that it will be necessary to use a high-pressure air hose to clean them.

SERVICE

The service requirements for hermetic units differ somewhat from conventional systems. However, with the correct tools and general knowledge of hermetic systems, any good refrigeration specialist will have very little trouble servicing these systems.

Some of the more common items that need attention are as follows: compressors, starting relays, motor protectors, cleaning, abnormal noise, door seals, restricted screen or capillary tubes, thermostats, mullion heaters, electrical shorts and opens, leaks, breaker strips, and moving the units.

POWER SUPPLY

Before connecting any electrical motor to a power supply, the following things must be checked.

* Frequencies - Most current in the US is 60 cycles. The frequencies overseas vary so much that each power source should be checked.

* Phase - A multiphase motor will not operate on single-phase current, neither will a single-phase motor operate on multiphase current, unless one of the phases is removed.

* Voltage - Turn on all electrical units on the circuit and check the voltage at the motor. If you have a low voltage condition, use another circuit. A domestic refrigerator should not have anything else plugged into the same outlet. Extra appliances can cause low voltage.

Installation and Operation

Domestic refrigerators are designed as self-contained units. However, here are some general items that you should consider when installing a new refrigerator.

* Remove the shipping bolts from the compressor, if necessary.

* Remove the shipping tiedown strips.

* Install the shelves, crisper, etc.

* Check the electrical supply.

* Level the box. Modern refrigerators that use a magnetic door gasket should be set so that the door will swing shut from a half open position.

* Plug in the unit.

* Turn the unit on and set the thermostat at the midrange.

* Instruct the user in the correct operation, cleaning, and maintenance procedures.

GENERAL INSTRUCTIONS. After installing a new domestic refrigerator, make sure the user thoroughly understands these general instructions: Keep the door closed as much as possible. Put all liquids in closed containers. Cool all foods to room temperatures before putting them in the refrigerator. Do not overload the box. Also make sure the user understands defrosting procedures, if necessary, the correct use of the cold control (thermostat), and correct cleaning procedures.

MOVING A REFRIGERATOR. Before moving a refrigerator, all of the loose parts (crisper, shelves, ice trays, etc.) should be removed or tied securely. Tie down the compressor: this keeps it from moving around and breaking a line. Cover the unit with a padded blanket (shipping blanket) and strap it securely to an appliance moving cart. The refrigerator can be turned over on its side if necessary. However, it is best to keep it in an upright position as much as possible.

When reaching its destination, the unit should be serviced the same as a new unit.

COLD STORAGE-REFRIGERATION COMBINATIONS

During the initial development of the domestic refrigerator, the freezing unit or section was small. It would hold two or three ice cube trays and that was about all. The customer began demanding more and more freezer space until some boxes are one-third freezer space. The freezer must be maintained at about 0°F while the refrigerator section is only 40 to 50°F. Several methods have been employed to maintain these two different temperature ranges within the same box.

Air Spillover Using One Evaporator (See figure 4)

This is the oldest method used to maintain two different temperatures. The cold air that flows (spills over) the frozen food compartment cools the regular refrigerator space. This system has disadvantages. During periods of light usage, the temperatures of the refrigerator space will become too cold. During periods of heavy usage, the refrigerator temperature will be too high even if the temperature of the frozen food area is normal.

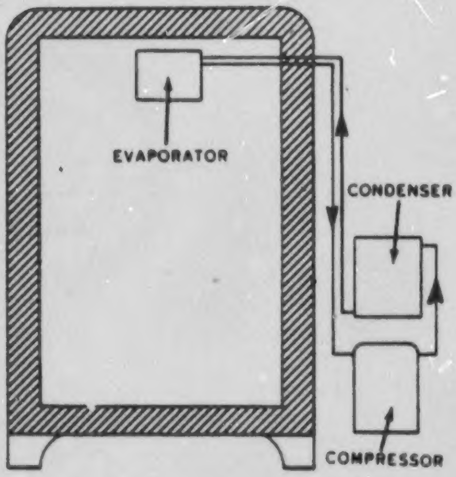


Figure 4. Air Spillover

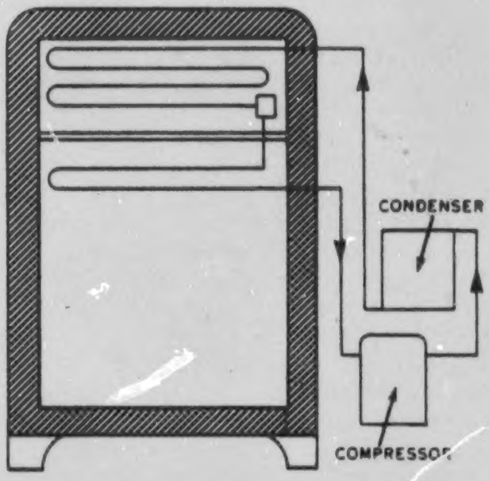


Figure 5. Refrigerant Spillover System

Refrigerant Spillover Using Two Evaporators (See figure 5)

In this system the tubing, evaporator size, and refrigerant charge is very critical. The liquid refrigerant goes to the coldest evaporator first. If this area needs refrigeration, all of the liquid is vaporized and the vapor is superheated in the second evaporator before going to the compressor. When the first evaporator is satisfied, the liquid will spill over into the second evaporator and be vaporized there. An accumulator at the end of the coldest evaporator aids in keeping the refrigerant from spilling over too soon.

The compressor is cycled by a thermostat on the warmest evaporator. The evaporator in the fresh food compartment is much smaller than the one in the freezer section. The thermostat cycles the unit off when the saturated vapor reaches the outlet of the medium temperature evaporator.

Metered Chilled Air System. (See figure 6)

This system is used on modern "no-frost" refrigerators only. It utilizes a finned, forced convection evaporator that is located in the frozen food compartment. A fan forces the air over the evaporator coil and over the food in the frozen food compartment. A critically sized duct runs from the evaporator to the fresh food compartment. Therefore, a metered amount of cold air is forced through this duct into the fresh food compartment. This air is very cold and is usually directed toward the top or sides of the box. If this cold air is allowed to strike a product directly the product will be frozen. Small holes permit the air to return from the fresh food compartment to the freezer compartment. Since the forced convection evaporator is in a low temperature area, it is necessary to use some form of automatic defrost.

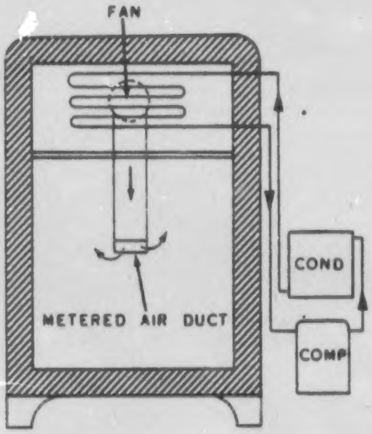


Figure 6. Metered Air System

Since the thermal bulb of the thermostat is not attached to the evaporator, it feels air temperature only. Most manufacturers place the thermal bulb in the freezer compartment; however, some place it in the fresh food compartment.

AIRFLOW. The freezer air is drawn into the return air duct, see figure 7, at the front of the freezer. It passes to the rear between the divider and freezer bottom. It is then drawn upward through the evaporator and discharged into the freezer section.

The sensing element of the cold control is located at the rear of the freezer air return duct, in the refrigerator section the refrigerator air is drawn into the refrigerator air return duct at the top front of the refrigerator section. It passes to the rear of the section between the styrofoam divider and the top of the refrigerator section. It is drawn upward through the cooling coil and discharged into the fan cover by the fan. Part of the air that is discharged into the fan cover is directed into the refrigerator air duct, which is mounted on the insulation side of the liner. The air then passes down the duct and enters the refrigerator section. The amount of air entering the refrigerator is carefully balanced with the amount of air entering the freezer to achieve proper temperatures in both sections.

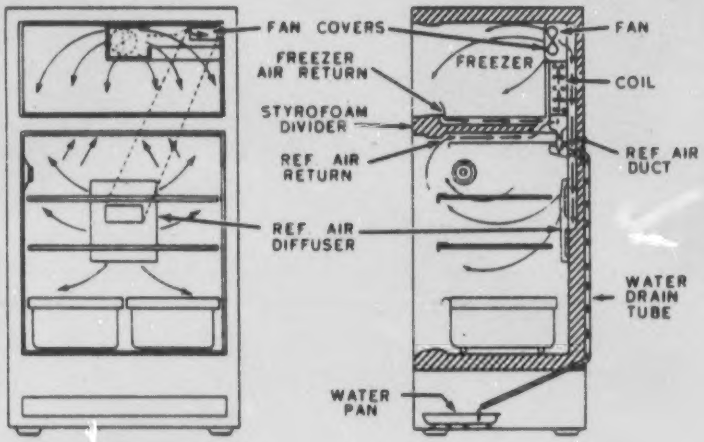


Figure 7. Airflow in A No-Frost Refrigerator

Today modern refrigerators use variations of the refrigerant spillover and metered air systems on their frost free refrigerators. The evaporators can be located anywhere such as in the lower portion or either side. The refrigerator operates basically the same as those previously listed. The side by side refrigerators tend to be larger in size, 20 to 30 cubic feet.

Domestic Freezers. Domestic freezers were first developed for the storage of frozen foods in the home. These boxes may be either the chest or upright type. The chest type operates more economically and the temperature fluctuations are not as great as with the upright. The upright type box was developed so that a large box would not take up too much floor space. The greatest disadvantage of the upright box is that each time the door is opened, the cold air spills out and is replaced with warm air. This not only causes the unit to operate longer but also causes a large temperature fluctuation within the box.

These freezers are similar in design and operation to that of the domestic refrigerator, except for the lower temperatures that they maintain.

Defrost Systems

All modern domestic refrigerators have some type of automatic defrost. Two types of automatic defrost in general use are: hot gas and electrical. In general all defrost systems have the following major components.

DEFROST TIMER. This is an electrical clock that energizes the defrost systems. There are two different methods of operating the clock timer. (1) Clock timing. This is the simplest and most common method used. An electric clock is wired to the plug-in cord. Any time the unit is plugged in, the clock is running. Some of these timers are set to defrost once every 12 hours, while others defrost every 6 or 8 hours. (2) Running time. The electrical clock is connected to the compressor circuit. Therefore, the clock runs only when the compressor is operating. After a given number of hours of operation, usually about 4 to 8, the timer energizes the defrost system.

DRAIN TROUGH. This unit is located below the evaporator to catch the defrost water as it drips off of the evaporator.

DRAIN TROUGH HEATER. An electrical heater located below the drain trough to keep the water from freezing before it has a chance to flow out the drain line.

DRAIN LINE. A piece of rubber or plastic tubing runs from the drain trough down to the drain pan below the refrigerator. If the drain line passes through the freezer area, it must be heated.

DRAIN PAN. A shallow plastic or metal pan located beneath the refrigerator. The defrost water from the evaporator collects in this pan and is evaporated by the heat of the compressor, oil cooler circuit, or condenser.

HEATING MECHANISM. For satisfactory operation, particularly in the freezer section, the time it takes to defrost the evaporator must be held to a minimum. This is accomplished by rapidly heating the evaporator with the hot condenser gas or an electrical heating coil.

DEFROST THERMOSTAT. This unit has several different names; defrost thermostat, termination thermostat, defrost limit switch, and safety control. Regardless of what these units are called, they all work in the same manner and have the same functions.

The unit is a small circular (about the size of a quarter and 1/4 to 3/8-inch thick) plastic or bakelite disc with two wires attached. It is located on and attached to the evaporator. The internal mechanism consists of a bimetal element that is open at 37 to 40°F and is closed at 18 to 24°F. It has two purposes:

- Keeps the defrost heater from getting hot unless the evaporator is cold.
- Stops or terminates the defrost cycle when the evaporator reaches 37 to 40°F.

HOT GAS DEFROST SYSTEM. Figure 8 illustrates a typical hot gas defrost system. The defrost timer opens the solenoid valve allowing the hot condenser gas to flow through the bypass (dashed line) into the evaporator. The hot gas gives up its heat and melts down the drain line to the drain pan. The heat from the condenser evaporates the water. The drain trough heater keeps the water from freezing before it flows out the drain line.

Some of the hot gas condenses in the evaporator. To eliminate a liquid lock in the compressor, the liquid refrigerant is vaporized by an electrical heating element on the suction line.

Advantages. (1) Cheap operation - by using the heat in the hot gas, the requirement for electrical power is reduced, (2) Fast operation - the hot gas is in direct contact with the tubes in the evaporator. Therefore, the ice is melted very rapidly.

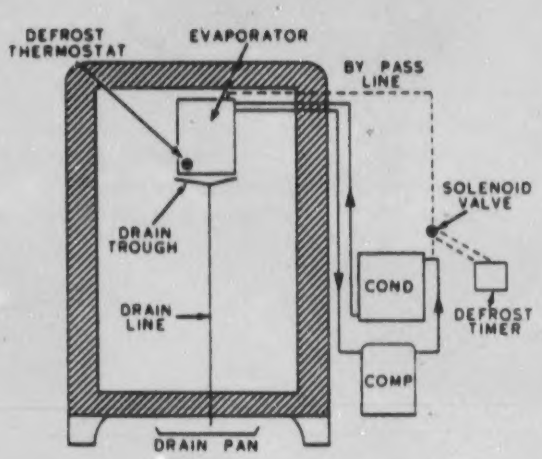


Figure 8. Defrost System

Disadvantages. The hot gas defrost system is more difficult to troubleshoot than the electrical. If the box is located in a low ambient temperature area, there will not be enough heat in the hot gas to completely defrost the evaporator. The ice will continue to build up on the evaporator until it must be defrosted by hand.

SERVICE AND MAINTENANCE. Hot gas defrost systems are subject to the following three malfunctions or troubles:

- Solenoid Valve Stuck Open. The symptoms are: compressor operates all the time, box temperature high, low side pressure high, high side pressure low, and bypass line warm. Checking procedures for these symptoms are: operate the system and tap the valve with a rubber hammer. If tapping causes the valve to close, it indicates the valve is faulty and should be replaced. If the valve does not close, unplug the unit and disconnect the electrical wires at the solenoid valve. Operate the unit. If the valve closes, the trouble is in the defrost timer. If the valve does not close, replace the valve.

- Solenoid Valve Stuck Closed. The symptom is: the system will not defrost. The checking procedures are unplug the unit and disconnect the electrical wiring at the solenoid valve. Connect an external power source to the solenoid. Operate the unit. If the solenoid valve opens, the trouble is in the defrost timer. If the valve does not open, the valve must be replaced.

- Solenoid Valve Leaking. The symptoms are: the low side pressure is high, the high side pressure is low and there is a high box temperature. Compressor runs all the time and the bypass line is warm. The checking procedures are: the first four could be caused by a bad compressor. The last symptom indicates that the trouble is in the solenoid valve and not the compressor.

ELECTRICAL DEFROST SYSTEM. This defrost system is very simple. It consists of an electrical heating element wound around and attached to the evaporator. The defrost timer turns the compressor off and turns the defrost system on. Electricity flows through the heating element and heats it up. The heat melts the ice on the evaporator. As soon as the evaporator reaches 37 to 40°F, the defrost thermostat turns the defrost system off.

Advantages. Complete or positive defrosting of the evaporator: system is simple and easy to troubleshoot.

Disadvantage. The cost of operation.

SERVICE AND MAINTENANCE. Electrical defrost systems are subjected to the following malfunctions or troubles:

- Unit Will Not Defrost. The symptoms are, with the unit operating: box temperature high, very little air coming through the evaporator, and the evaporator covered with frost. Checking procedures are unplug the unit, defrost the evaporator, and disconnect the electrical wiring at the element. If the heating element gets hot, it is satisfactory, and the trouble is in the timer. If the heating element does not get hot, it is faulty and must be replaced.

- Unit on Defrost and Will Not Change Back to Normal Operation. The symptoms are: box temperature high, evaporator completely defrosted, compressor hot operating, and the defrost heating element is hot. Checking procedures: the first three symptoms could be caused by several different conditions. The fourth symptom indicates that the trouble is in the defrost timer.

- Unit Will Not Defrost Completely. The symptoms are: unit has a long on-cycle, box temperature high, small amount of air coming through the evaporator, and part of the evaporator covered with frost. Checking procedures: the symptoms, particularly the fourth one, indicate that the defrost thermostat is stopping the defrost cycle too soon. Replace the defrost thermostat.

DEFROST SYSTEM WIRING DIAGRAM. There are several types of defrost timers used on domestic refrigerators. The defrost timer is illustrated in figure 9. This timer consists of four major components. They are as follows: an electric motor that runs continuously, a rotor (with a lobe) that provides two defrost cycles for each rotation, a reset solenoid, and two sets of contact points, one set is always open when the other set is closed. During normal operation, as shown in figure 9, electrical current is supplied to the compressor through the closed contact points 2 and 3. When the rotor moves far enough, movable contactor 3 moves up on the lobe and opens contact points 2 and 3 and closes contact points 3 and 4. Current is now supplied to both the defrost and drain heaters. When the evaporator warms up to 37°, the defrost thermostat (defrost limit switch) opens and stops (terminates) the defrost cycle by energizing the reset solenoid, which opens terminals 3 and 4 and closes 3 and 2 to start the compressor.

The wiring diagram in figure 9 is for the electrical defrost system. This same type of timer can also be used with hot gas defrost systems by substituting a solenoid valve for the defrost timer.

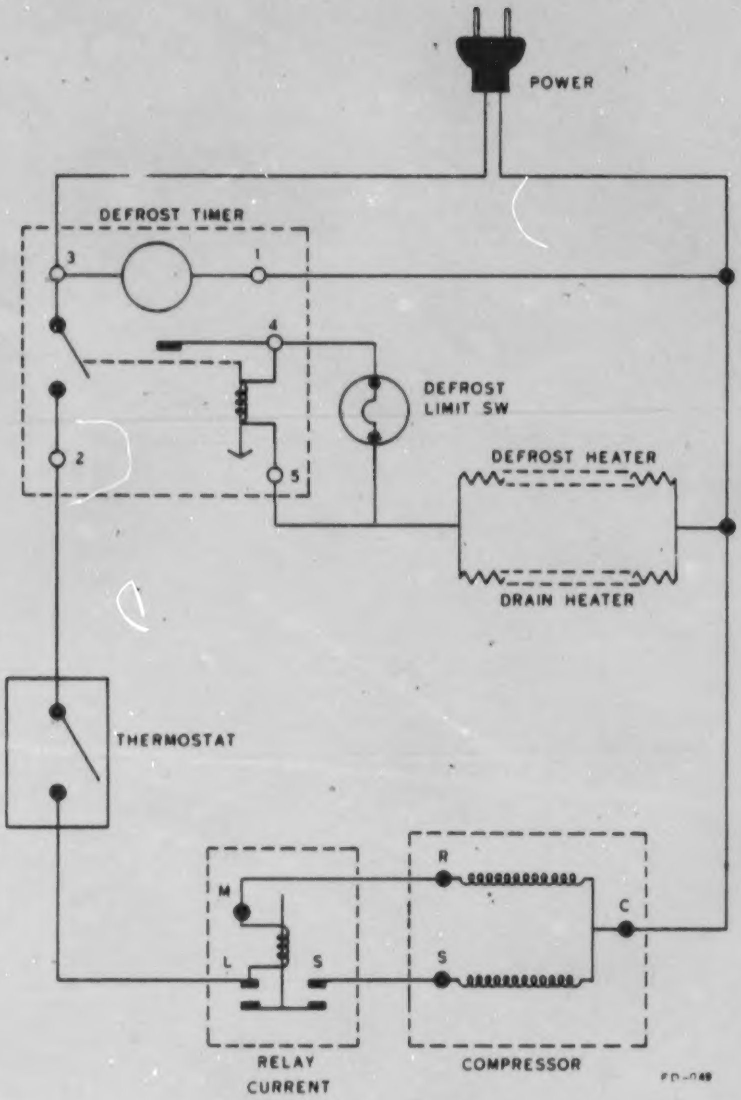

POWER
DEFROST TIMER
3
1
4
DEFROST
LIMIT SW
DEFROST HEATER
2
5
DRAIN HEATER
THERMOSTAT
R
M
C
L
S
S
RELAY
CURRENT
COMPRESSOR

Figure 9. Defrost Timer

SERVICING HERMETIC UNITS

It takes a qualified refrigeration specialist to troubleshoot and service hermetic units. Very often one symptom of trouble may be the result of several different malfunctions. It may take considerable time to eliminate all of the possible troubles. Listed below are some of the more common maintenance problems.

24

Replacing Filter-Drier

Most hermetic units have a filter-drier installed at the bottom of the condenser between the condenser and capillary tube. Occasionally you will find a drier installed between the outlet of the capillary tube and inlet of the evaporator.

The strainer (it may be a filter-drier) at the entrance of the capillary tube is placed there to catch all types of foreign matter before it enters the tube. In many cases, if you suspect a stopped-up capillary tube, you will find the restriction in the strainer.

A restricted or stopped-up capillary tube (filter-drier or strainer) will produce the following visible symptoms: box temperature high, unit runs all the time, and the evaporator totally or partially defrosted. A low charge will indicate these same symptoms.

Checking Procedures

Install the manifold gage assembly and check the low and high side pressures. On an initial restriction, high head pressure and low suction pressure will be indicated.

NOTE: If the high side is normally too low and the low side is very low, the capillary tube may also be restricted.

Use a six-inch flat file and mark each side of the capillary tube just as it leaves the strainer.

CAUTION: Put on goggles and use extreme caution before proceeding with the next step.

Use a pair of pliers and break the capillary tube at the point where you marked it with the file.

Check each end of the capillary tube.

a. Liquid refrigerant should pour out of the strainer unrestricted.

b. Gaseous refrigerant should come out of the capillary tube slowly.

NOTE: Remember, you have a lot of restriction in the capillary tube. If the restriction is in the strainer, remove it and install a filter drier.

NOTE: A partially restricted strainer will have a temperature drop across it.

If the restriction is in the capillary tube, it will usually be within three or four inches of the end.

Cut off about four inches of the bottom end of the capillary tube.

Apply refrigerant pressure to the low side of the system.

Check to see if the capillary tube is open. 253

NOTE: If the capillary tube is still restricted, it must be either cleaned or replaced.

If the filter-drier is restricted, replace it as follows:

Remove the old filter-drier.

Install an access fitting in the low side.

NOTE: Install the access fitting tube on the compressor if possible. Install an access fitting in the high side.

NOTE: Install this fitting near the filter-drier.

Install the filter-drier.

Use normal service procedures and place the equipment back in operation. It is much easier to clean a capillary tube than to replace it. There are several commercial capillary tube cleaning tools on the market. Some of these tools will produce a pressure of 15,000 psi.

If a capillary tube cleaning tool is not available use the following procedures:

Remove the breaker strips.

Disassemble the unit enough so that the capillary tube and suction lines are exposed.

Remove the capillary tube and suction line.

Fabricate a new suction line.

Solder the new capillary tube to the new suction line.

Install the new suction line and capillary tube.

Install a filter-drier at the outlet of the condenser.

Pressurize and leak check the system.

Reassemble the refrigerator.

NOTE: Make sure you do not bend or kink the suction or capillary tube.

Evacuate and charge the system.

NOTE: If possible, the capillary tube should be installed so that some of the surplus can be coiled at the top of the unit just before the tube enters the evaporator. The remaining surplus tubing should be coiled at the bottom of the unit.

The procedures outlined above are for general discussion purposes only. Actually procedures will differ between types, models, and manufacturers of equipment.

Capillary Tube Selection

For maximum efficiency the exact replacement should be obtained from the manufacturer, however a general replacement kit can be purchased through normal supply channels; instructions will be furnished with the kit. The two things you need to know are the length and the inside diameter.

ACCESS VALVES

In order to check or service a hermetically sealed system that has no servicing valves, an access valve of some type must be installed. There are numerous types available on the open market, the Air Force uses two of these, the Schrader Valve and the Line Tap Valve.

Schrader Valve.

- One that is soldered into the system, becoming a more permanent installation.
- Loss of refrigerant charge when installed.
- Requires a charging hose with special insert to depress the valve core.
- Valve core is removable (same as the type used on automobile tires) CAUTION: Remove valve core before soldering into system to protect the seal.

Line Tap Valve.

- Valve is clamped around the tubing, not a permanent installation.
- Installed with no loss of refrigerant.
- Some types require a control valve for servicing.
- The gasket material on most of these valves is designed for high temperatures (discharge line).
- Install valve on clean, straight, round tubing.

One type of line tap valve is designed for use on only the size tubing specified. This valve also requires the use of a control valve used to screw the piercing needle in and extract it for servicing. The control valve fits the full size range of these valves.

Another type line tap valve is designed for various sizes of tubing, with the aid of shims that come with it. It does not require a control valve. The piercing needle is spring-loaded to the closed position and by inserting a small adaptor, replacing the cap we depress the needle and pierce the line. The adaptor is removed and from then on a charging hose with a depressor insert (type used on Schrader valves) is used for servicing the system.

To use the electronic leak detector, proceed as follows

- Plug in the unit and allow it to warm up.
- Adjust the sensitive knob until the unit stops whistling.
- Place the probe nozzle at the metered leak and adjust the sensitive knob until the unit whistles.
- The unit is now ready for use.
- Move the probe nozzle over the complete system.

NOTE: Move the nozzle very slowly.

The unit will whistle when the nozzles find a leak.

NOTE: After operating one hour, the unit must be turned off and allowed to cool for one hour before being used again.

This leak detector works very well where the unit to be tested is a "refrigerant free area." Manufacturers often place their completed refrigeration systems in a refrigerant free booth and check them with an electronic leak detector. This test guarantees the system is free of leaks before it leaves the factory.

Adding Oil to a Hermetic System

It is very seldom necessary to add oil to a hermetic system. These systems contain the correct oil charge when they leave the factory. Since oil is not used up in the normal operation of a refrigeration system, the oil charge will remain correct (unless lost through a leak) throughout the life of the equipment.

There are two conditions that require changing the oil; water in the system and excessive oil leakage.

Water in the system - It is practically impossible to get water out from under oil in a compressor. If the system becomes contaminated with water, it is necessary to remove the oil from the compressor before starting the following drying procedures.

Purge the refrigerant from the system.

Remove the compressor from the system.

Pour the oil out of the suction line connection.

NOTE: Measure the oil in a graduated glass cylinder or other suitable container.

Place the compressor back in the system.

Evacuate the complete system.

LEAK DETECTORS

Soap bubbles have been used for years to check for leaks in all types of systems containing pressure. These include air, natural gas, carbon dioxide, refrigerant, and all other types of vapor and gases.

Soap bubbles work very well as leak detectors around such things as service valves packing, gasketed surfaces, flare nuts, and soldered connections. Obviously, it would be impossible to apply soap bubbles to a complete refrigeration system. You can use a halide leak detector to find the general location of a leak and then use soap bubbles to pinpoint its exact location.

Electronic Leak Detector

The electronic leak detector pictured in figure 10 is designed to find very small leaks. It is so sensitive that you can find a leak as small as one ounce a year. This instrument is so sensitive that it is very difficult to use under normal shop conditions. There is always some refrigerant in the air in a refrigeration shop. This instrument will indicate a leak just about anywhere around the shop.

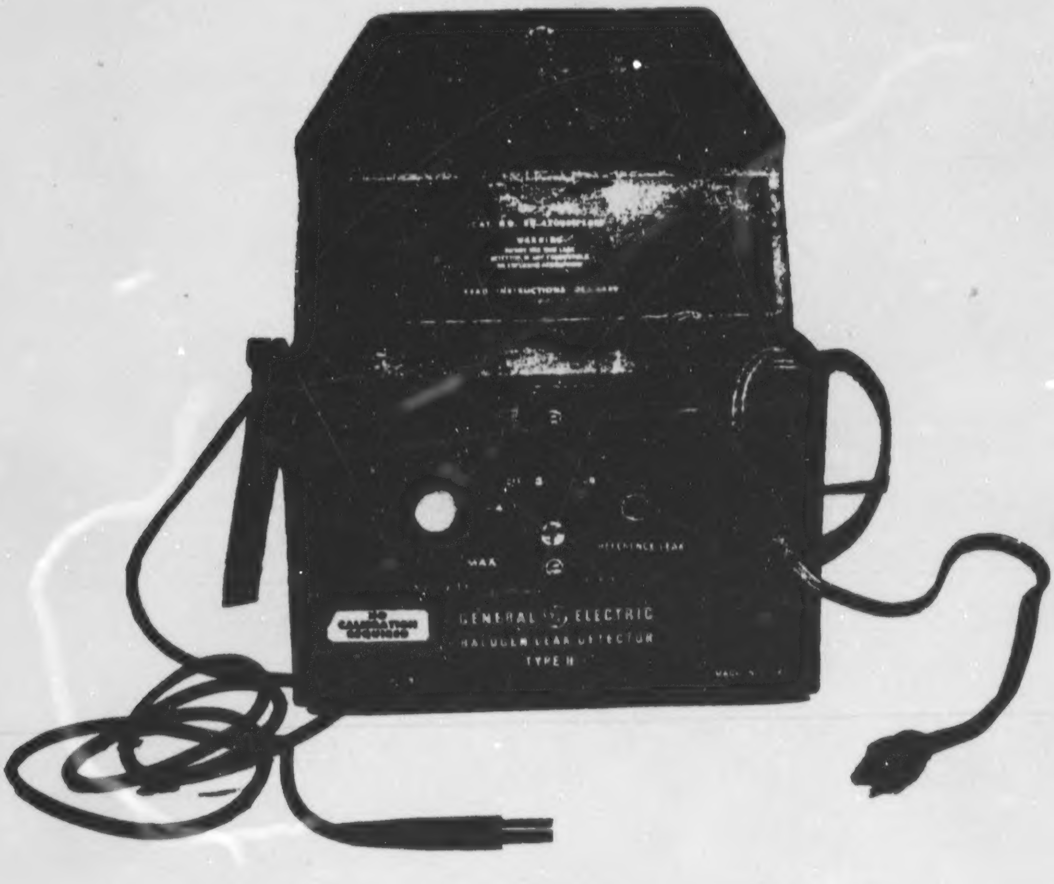


Figure 10. Electronic Leak Detector

NOTE: To dehydrate a refrigeration unit that contains liquid water, the complete system must have a temperature of 100°F or more and be under a vacuum of 50 microns or less for three or four days.

After the drying procedures are complete, place a quantity (more than the required charge) of oil in a graduated glass cylinder.

Place the end of the purge line in the oil.

Allow the vacuum in the system to pull the correct amount of oil into the compressor.

NOTE: Do not allow the end of the purge line to come out of the oil.

Excessive oil leakage - In the case of excessive oil leakage, DO NOT guess at the amount lost and then add that much to the system. The correct procedure is to drain all the oil from the compressor and then add the correct amount according to the manufacturer's specifications.

Charging Hermetic Units

Hermetically sealed units normally use a capillary tube refrigerant control. Therefore, the refrigerant charge is critical. There are two methods normally used to charge hermetic units. These methods are called the weighted method and the direct method.

The weighted method of charging is a method whereby the exact amount of refrigerant is determined by observing the data plate and then just that amount is weighted and charged into the system.

With this method the refrigerant is transferred from a refrigerant drum into a high-pressure translucent cylinder, where it can be seen and measured on a scale graduated in ounces of refrigerant. Having weighed the refrigerant this critical charge can now be placed into the unit being serviced.

CHARGING EQUIPMENT. There are several manufacturers producing charging equipment under such names as charging panels, charging cylinders, charging stations, etc. The using procedures differ with manufacturers.

CHARGING PANEL. As stated previously the refrigerant is first transferred into the translucent cylinder where the liquid level is seen and measured on a fixed refrigerant scale (graduated in ounces). This equipment has a disadvantage in that the volume of liquid as indicated by the liquid level will vary with changes in ambient air temperature and as a result erroneous measurements could be made. Charging equipment which will compensate for these temperature changes are available and are discussed next.

CHARGING CYLINDER (TEMPERATURE COMPENSATED). The charging cylinder is basically the same as the charging panel except that it has the ability to compensate for temperature changes and may be used for charging refrigerant 12, 22, 114, and on special models R-502.

The portable charging cylinder will be used as follows:

1. Fill the cylinder with the required refrigerant.
2. Turn the outer cylindrical dial to correspond to the type of refrigerant being used.
3. Adjust the scale to compensate for volume change due to ambient temperature.
4. Read the pressure on the pressure gage mounted on the top of the charging cylinder which indicates internal pressure of the charging cylinder. Because of the pressure temperature relationship, the temperature determines pressure, the pressure in turn determines the volume.
5. Turn the plastic calibrated shroud which surrounds the cylinder to the proper volume-pressure chart (which corresponds to the indicated pressure on the charging cylinder gage).
6. According to the charge required in the unit, record (or note) the amount in the cylinder at the beginning of charging. Charge the system anticipating the amount that will remain after charging and stop at this level.

CHARGING STATION. One company manufactures a charging cylinder mounted on a portable handcart, complete with MGA and vacuum pump.

An example of a charging panel and a portable charging station complete with manifold gages and vacuum pump are illustrated in figure 11.

Advantages: Fast. A given amount of refrigerant can be put in the system in a relatively short time. It removes guesswork. If you know exactly how much refrigerant your unit requires, this amount can be placed in the system. Then it should operate satisfactorily. Inexperienced personnel can use it with very little instruction. Charging stations are used on manufacturers' assembly lines. The manufacturer can assign an inexperienced person the job of charging the units. This works satisfactorily as long as the person charging the unit observes details carefully. The charging station can also be used in areas where an experienced refrigeration service man is not available.

Disadvantages: There may be some differences in the operating characteristics between two units of the same model. Therefore, one unit may require more or less

Figure 11. Charging Panel - Charging Station

refrigerant than another. A repaired unit does not have the same operating characteristics as a new unit. The fact that you are charging the unit indicates that some major maintenance or repair function has been performed on the system. This maintenance or repair may have changed the operating characteristics of the system. Some units do not list the correct charge.

Direct Charging

The charging procedures listed here are for general discussion purposes only. The actual step-by-step procedures are outlined in the workbook.

Install an access valve in both the low and high sides of the system.

Pressurize and leak test the system.

Evacuate the system. If you attempt to evacuate the system through the low side only, all the vapor and moisture in the high side must be pulled through the capillary tube. As you can see, this would be very difficult and would require a long time.

Break the vacuum with refrigerant.

Evacuate the system. Break the vacuum with refrigerant.

Turn the unit on and give it a good slug of vapor.

Listen at the outlet of the capillary tube. There is a little refrigerant in the system. You should hear a gurgling, hissing sound as the refrigerant feeds into the evaporator.

Feel of the evaporator right where the capillary tube connects. You will feel a cold spot. This spot may actually frost. If you stopped charging at this moment, the little frost spot would remain just a little frost spot.

Give the system a little more refrigerant.

Chick the size of the frost spot. It will get larger in relation to the amount of refrigerant added.

Continue adding refrigerant and checking the evaporator until it is completely frosted.

Check the pressure on the gages. The low side should read about 2 to 5 psi.

Allow the unit to operate for 12 to 24 hours. During this time, periodically check the low and high side pressures and the frost on the suction line. Generally, it is a good practice to slightly overcharge the system. When the frost appears on the suction line, bleed off the excess until the frost line recedes into the box.

Observe the box until it has cycled (turned off and on) several times.

Observe the suction line when the unit turns ON. If any frost appears at this time, bleed off a little more refrigerant.

The system is now ready to return to the user.

Do not attempt to charge a capillary tube system in a few minutes. Take your time. It is good practice to start the charging procedures early in the morning, and observe the operation of the box throughout the day. Work on something else while the box is operating. It will not take but a moment to observe it occasionally during the day.

There is no better way to charge a capillary tube system than the procedures outlined here.

Observe the following rules when charging a capillary tube system: (1) Take your time. (2) Evacuate the system before charging. (3) Let in the refrigerant gradually. (4) Observe the low side gage, the high side gage, and frost on the evaporator or suction line while charging. (5) Unit must operate satisfactorily for 12 to 24 hours before being returned to the user.

The procedures discussed here will hold true for any capillary tube system where the evaporator operates at temperatures below freezing. Most of these procedures will also hold true for window air conditioners.

ADVANTAGES OF DIRECT CHARGING: The procedure will work on all capillary tube systems. This method does not require special charging equipment.

DISADVANTAGES OF DIRECT CHARGING: Requires more time. It requires a trained refrigeration specialist who can trust his own judgment.

Starting Relays

Hermetic compressors normally use an induction motor with two windings: a start winding and a run winding. This requires some type of switch to automatically disconnect the start winding as soon as the motor reaches approximately 3/4 of its rated rpm. The automatic function is performed by a switch known as a starting relay.

TYPES:
1. Current
    a. open coil
    b. enclosed coil
2. Time Delay
    a. Hotwire
    b. Thermal
3. Potential

CURRENT RELAY. The current relay is used on low torque, fractional horsepower motors.

Advantages: Smaller and cheaper.

Disadvantages: Points open during high current draw resulting in arcing of its points.

Operation: This relay operates on the principle that current draw is highest when the motor is starting than at any other time. The points of the relay are normally open when the compressor is not operating. When the thermostat closes, the current rushes in and magnetizes the relay coil. This causes the relay points to close. After the motor reaches two-thirds to three-rourths of its rated rpm, the current flow will drop and the magnetic field around the relay coil will decrease. The points will then be opened by gravity. Open contacts cut the start windings out of the circuit. The run winding takes over. The current relays have three terminals usually identified as L, S, and M. This relay can be used with a starting capacitor. If a start capacitor is used, it will be located in the start lead between the compressor and the relay.

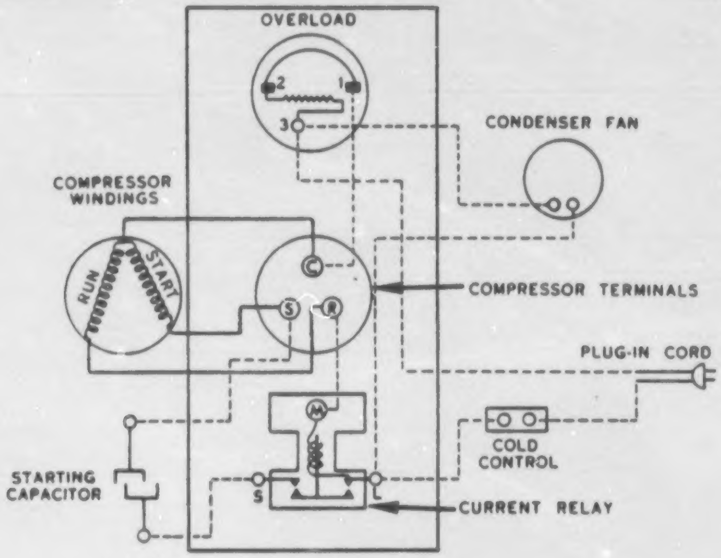


Figure 12. Wiring Diagram (Open Coil Relay)

Open Coil Relay (Current). The wiring diagram for this relay is illustrated in figure 12. The dash lines are electrical wiring connections. The solid lines are internal connections between the compressor terminals and motor winding.

Study this diagram until you understand it thoroughly. If possible, go to a unit that uses an open coil current relay. Locate and identify each component and electrical connection illustrated in this diagram.

Enclosed Coil Relay. An enclosed coil relay is illustrated in figure 13. The operation of this relay is the same as the open coil type. However in this case the coil is not seen. It is enclosed in a housing with the points. If you study both diagrams, you will see that nothing but the compressor wires go through the thermal overload. The thermal overload is sized only for the compressor amperage.

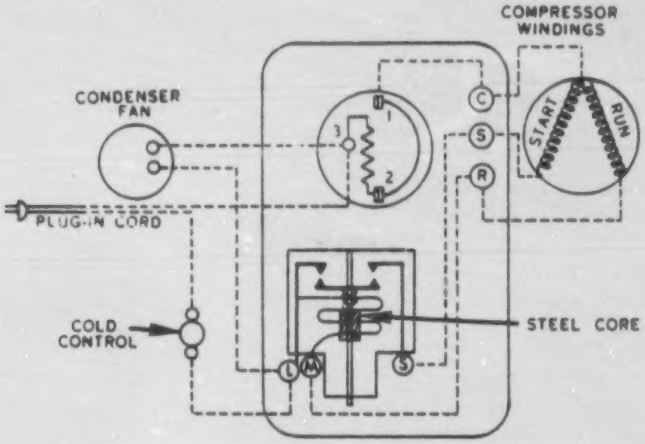

COMPRESSOR WINDINGS
CONDENSER FAN
C
S
R
START
RUN
1
2
3
PLUG-IN CORD
COLD CONTROL
STEEL CORE
L
M
S

Figure 13. Wiring Diagram (Enclosed Coil Relay)

Study the wiring diagram until you are thoroughly familiar with it. Procure an enclosed coil relay and check the electrical connections. Most enclosed coil relays come with the run and start leads attached.

TIME DELAY RELAY. Thermal and hot wire are both used on low torque, fractional horsepower motors. These relays have their own built-in safety device and do not require thermal overloads.

Hot Wire Relay. This relay operates on the principle that electricity passing through a conductor produces heat, and heat makes metals expand. Figure 14 illustrates a typical hot wire relay installation.

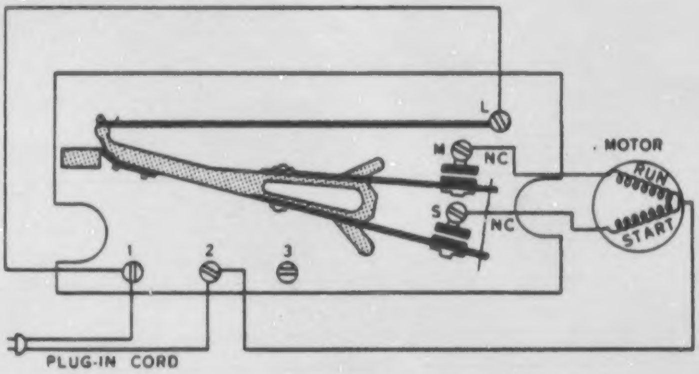

L
M
NC
S
NC
MOTOR
RUN
START
1
2
3
PLUG-IN CORD

Figure 14. Hot Wire Relay

The contact points, see figure 14, at M and S are normally closed. When the motor control closes, current flows from the line to terminal 1 and up to terminal L. The current flows from terminal L down the hot wire and through the internal mechanism, to the M and S contact points. From there it flows through both the run and start winding and out the common terminal to the line. At this moment current is running through both the run and start windings and the motor starts. At startup, there is a large current flow through the hot wire. The hot wire gets hot and expands. This small increase in length allows the internal mechanism to move enough to open the start contact points. This stops the flow of current through the start winding but the motor continues to operate on the run windings. If the current flow through the run windings becomes excessive, the hot wire will again increase in length and the internal mechanism will move enough to open the M contact points and stop the motor.

It is obvious that the amount the hot wire will expand at a given temperature is very critical.

Disadvantages. The hot wire relay is not as reliable as the current relay because the tension on the wire is affected by ambient temperature. It is difficult to troubleshoot. These units will operate just perfectly as long as you are watching or checking them. However, at the most inopportune time, such as nights, holidays, or weekends, the start contact points will fail to close on the "off" cycle.

Hot wire relays have been used on a great number of domestic refrigerators in the past. However, at the present time most manufacturers are using the current relay which is smaller and less troublesome.

When the box temperature increases and the motor control closes, the compressor will fail to start, because the start contact points are open. The unit continues to warm up and defrost. When the user comes in and opens the door he finds the box warm and the evaporator defrosted. He calls a serviceman, but the opening and closing of the door has "jarred" the unit enough so that the contact points close. When the serviceman gets there, the unit is operating perfectly. Troubles like these can cause a refrigeration serviceman many headaches.

Thermal Relay (see figure 15). This relay operates on the principle that a bimetallic element will bend when heated. With the cold control open, both contact points are closed, as illustrated in figure 15. When the cold control closes, current comes in terminal "L" and goes out both terminals "M" and "S." The compressor is at rest so there is a large current flow through the heater and the left-hand bimetal strip. The bimetal strip gets hot and moves to the right, opening the contact points. The start windings are cut out of the circuit and the compressor continues to operate on the run winding. There is enough current going through the run winding to keep the heater hot enough to keep the bimetal strip from returning to its original position. When the cold control opens, the heater will cool off, and the bimetal strip will return to its original position.

The overload protection is provided by the right-hand bimetal strip. During normal operation, the right-hand contact points are closed. High current flow will heat the bimetal strip, and it will move to the left, opening the contact points. As soon as the bimetal strip cools off, it will return to its original position.

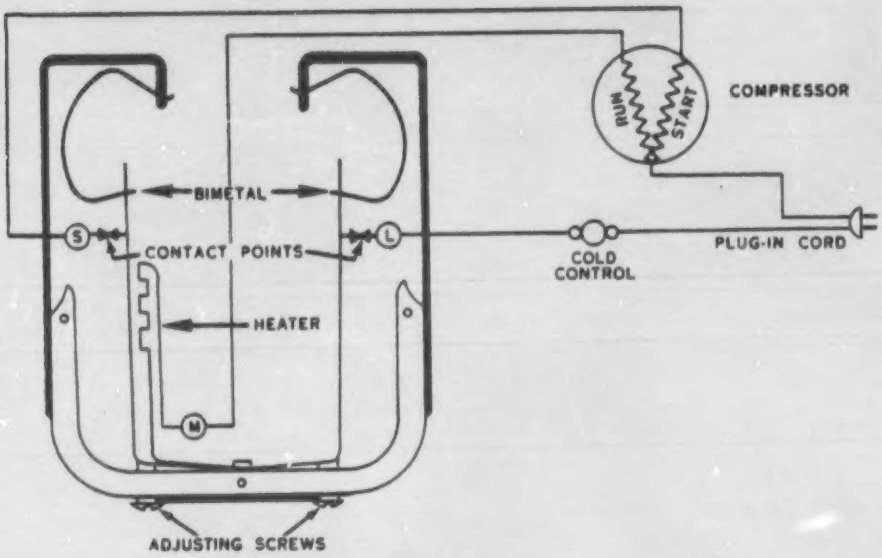


Figure 15. Thermal Relay

SOLID STATE RELAY

Solid state starting relays are relatively new just being introduced to the field in the past few years. They are primarily used to replace the current, hot wire, and thermal relays which are used on fractional horsepower and low torque motors. It is possible that one relay would fit every refrigerator and most small water coolers on an Air Force Base.

The major advantages that the solid state relay has over the other relays are:

A. **Cost**
Its cost is about one fourth that of other relays.

B. **Reliability**
Other relays have a fail safe factor of ten thousand to fifteen thousand trouble free starts, where as the solid state is rated over fifty thousand trouble free starts.

******** THEY DO NOT USE CONTACTS ********

C. **Flexibility of use**
One solid state relay may be used for several size motors, where time delay and current relays must be sized for each motor. Solid state relays may be used to repair fractional horsepower open type motors with defective starting mechanisms.

D. **Simplicity of installation**
They can be installed in a matter of minutes and also cut the number of parts that must be maintained in stock.

The solid state relay (see figure 16) operates on the principal that heat will change the molecular structure of the filter grid to impair current flow to the start winding thus removing the start winding from the circuit. Applied voltage will continue to keep the filter grid hot until the thermostat opens the circuit stoping the compressor.

An external overload is required when using a solid state relay to protect the compressor motor from overload.

A space connector is wired on one side of the relay. This is used to install a start capacitor if required (or may be used to install a hard start kit).
THIS WIRE MUST BE CONNECTED TO THE START TERMINAL ON THE COMPRESSOR *

The run terminal and all excessories (condensor fan heaters, etc.) and a lead from the power source will be connected to the other wire with a wire nut.

The common terminal on the compressor will be wired through the overload back to the power source

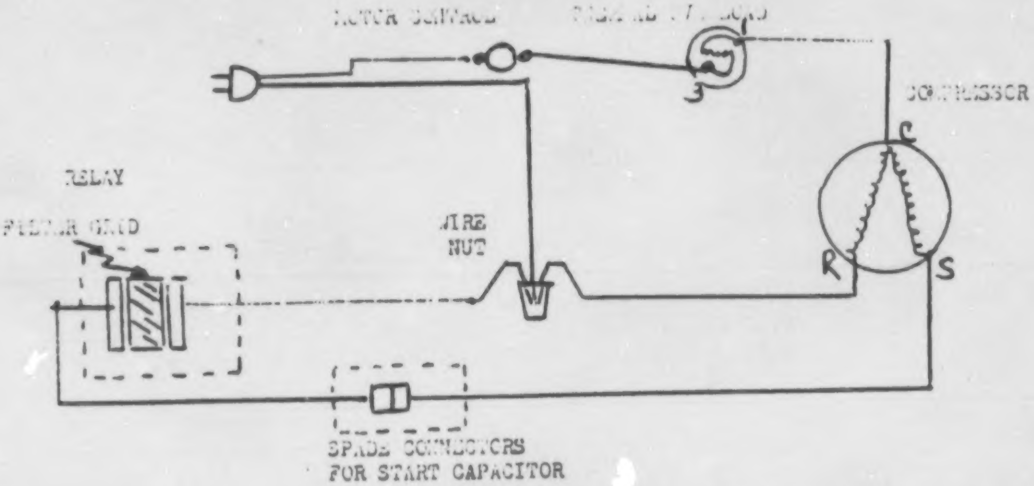


Figure 16. Solid State Starting Relay

POTENTIAL RELAY

Advantages. The points open during low current thus reducing electrical arcing.

Disadvantages. Potential relays are larger and cost more than the current relays.

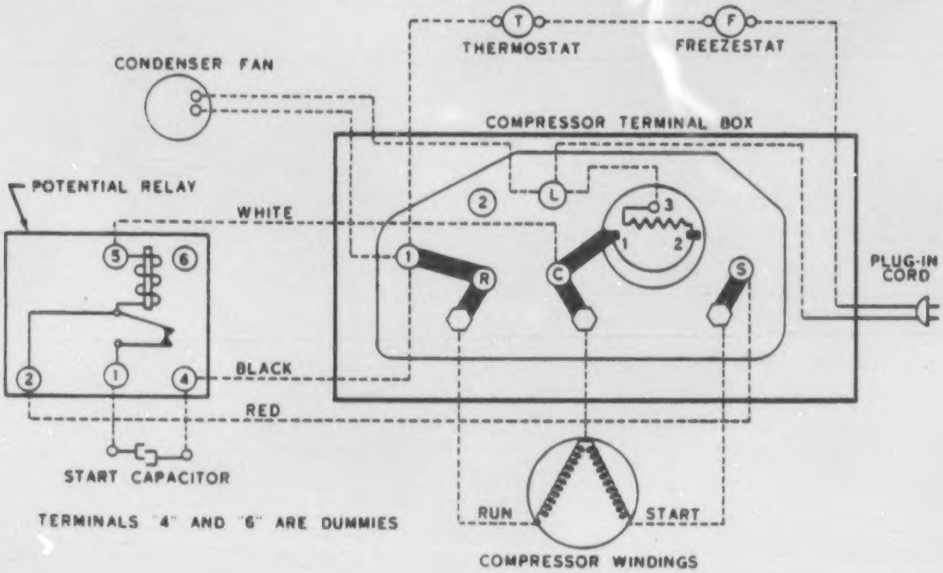
Application. Systems use high torque motors and automatic or thermostatic expansion valves. This relay is position sensitive to the extent that it must be mounted in the same position as the original factory application.

Typical Potential Relay Wiring Circuit. A typical potential relay wiring circuit is illustrated in figure 17. This is the wiring diagram of a glass filler type water cooler. After thoroughly studying this circuit, locate and identify each of the major components, terminals, and electrical conductors.

Operation. The freezestat is for safety purposes only and is normally closed. It only opens if the temperature of the water drops down near 33°F, see figure 17. When the thermostat closes, current can flow from the plug-in cord, through the freezestat and thermostat to terminal 1. At this moment three circuits are completed.

Condenser Fan Circuit. Current flows from terminal 1 through the condenser fan motor to terminal L and back to the plug-in cord.

Run Circuit. Current flows from terminal 1 through the conductor strip to terminal R. From terminal R, the current flows through the conductor strip to the compressor terminal. From this point it flows through the run winding (in the compressor), out the common terminal, through the overload, and back to the plug-in cord.


T
F
THERMOSTAT
FREEZESTAT
CONDENSER FAN
COMPRESSOR TERMINAL BOX
POTENTIAL RELAY
WHITE
5
6
2
1
4
BLACK
RED
2
L
3
1
2
1
R
C
S
PLUG-IN CORD
START CAPACITOR
RUN
START
COMPRESSOR WINDINGS

TERMINALS "4" AND "6" ARE DUMMIES

Figure 17. Potential Relay Wiring Diagram

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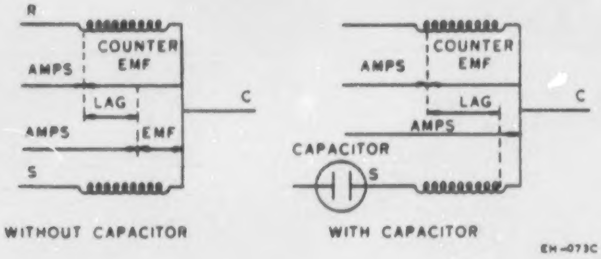
Start Circuit. Current flows from terminal 1 on the compressor terminal box to terminal 4 on the relay. From terminal 4 it flows through the start capacitor to terminal 1. From terminal 1 it flows through the contact points (which are normally closed) to terminal 2. The applied voltage is not strong enough to force current through the small high resistance wire in the coil. Therefore, at this moment there will be no current flow from terminal 1 to terminal 5. Current flows from terminal 2 to terminal S and then through the start windings (in the compressor) to terminal C. From this point it flows through the overload and out to the plug-in cord.

At this moment the compressor motor starts. As the motor comes up to about two-thirds of its rated rpm, the run winding induces a voltage into the start windings. This induced voltage is high enough to force current to flow from terminal C to terminal 5 and through the coil to terminal 2. From terminal 2 the current flows to terminal S and back to the start winding contact points in the relay. The motor is now operating on the run winding only. The contact points are kept open by the voltage that the run winding induces into the start winding.

CAPACITORS

Starting Capacitor

Starting capacitors are used to increase the starting torque of the motor. This is accomplished by cancelling the counter EMF in the start winding and increasing the lag between the run and start windings. See figure 18.



WITHOUT CAPACITOR WITH CAPACITOR

Figure 18.

Capacitors are rated in Microfarad (MFD). The MFD may be varied by 10 percent over the rating on the original capacitor. Starting capacitors are wired in series with the start winding. Some capacitors have a resistor across the terminals to reduce arcing of the contacts in the relay.

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Running Capacitor

Running capacitors are used to increase the power factor of the motor. It allows the use of the start winding and decreases the running amperage.

The MFD of the running capacitor cannot be varied, as it is in the circuit at all times and affects the amperage draw on the motor. It is wired between the run and start terminals of the motor with power or run terminal connected to the identified terminal of the capacitor. See figure 19.

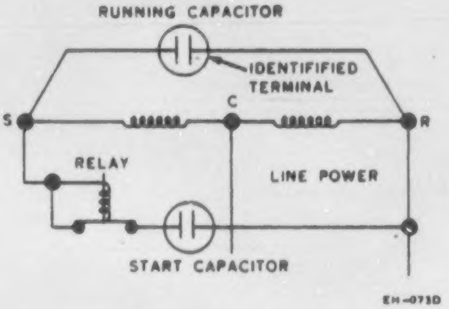
RUNNING CAPACITOR
IDENTIFIFIED TERMINAL
C
S
R
RELAY
LINE POWER
START CAPACITOR
EH-073D

Figure 19. Using a Run Capacitor

Capacitors Connected in Parallel

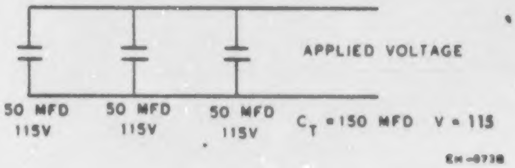
APPLIED VOLTAGE
50 MFD 115V
50 MFD 115V
50 MFD 115V
C_T = 150 MFD V = 115
EH-073B

Figure 20. Capacitors in Parallel

When capacitors are connected in parallel the total plate area is increased, and the MFD is increased. The distance between the plates is the same therefore the applied voltage must remain the same as the capacitors rated voltage. See figure 20. The formula is

$$C_t = C_1 + C_2 + C_3 \text{ etc.}$$

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When capacitors are connected in series the total plate area is the same but the distance between the plates is increased. Because of the increase between the plates, the MFD will decrease but the applied voltage to the capacitors can be increased. See example in figure 21. The formula is

$$C_t = \frac{C_1 \times C_2}{C_1 + C_2}$$

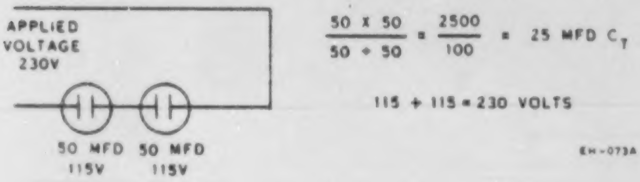

Figure 21. Capacitors in Series

Terminal Arrangement

Hermetic compressors employ two types of single-phase motors: the split phase and capacitor-start. On the housing containing the motor and compressor, you will find three terminals which connect to the start and run windings. These terminals are commonly referred to as the run, start, and common. Some of the possible terminal arrangements are illustrated in figure 22.

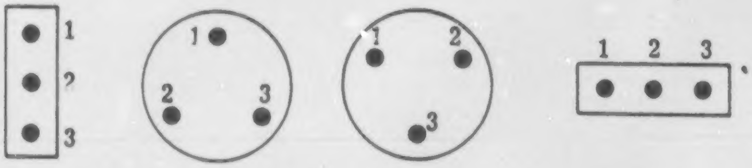

Figure 22. Possible Positions of Compressor Terminals

Sometimes the compressor terminals are known or marked. In this case you will not have any trouble identifying the compressor terminals.

Sometimes the compressor terminal arrangement is not known. Then it becomes a problem to determine just which is the common, start, and run.

To be able to correctly wire the system or replace the starting relay, the terminals must be known. One method is to measure the resistance across the terminals. Then, by deduction, find the R, S, and C terminals.

The first step is to measure the resistance across the terminals. This requires three readings, one across each set of terminals. Following is the procedure for measuring the resistance:

- Use an ohmmeter to take a reading between terminals 1 and 3. See figure 23. Write down this reading. In this case, it is 16 ohms.
- Take the second reading between terminals 1 and 2. Write down this reading. In this case it is 12 ohms.
- Take a third reading between terminals 2 and 3. Write down this reading. In this case it is 4 ohms.
- At this time attention should be given to the readings. The two low readings (12 and 4) when added together should total the highest reading. Should the low readings not total the highest reading taken, this would indicate a malfunction within the motor windings. This does not mean the motor will not operate. A check of the running amperage will normally read about or below the rated amperage.
- Terminal Readings: (Figure 23.)

1 and 3 = 16

1 and 2 = 12

2 and 3 = 4

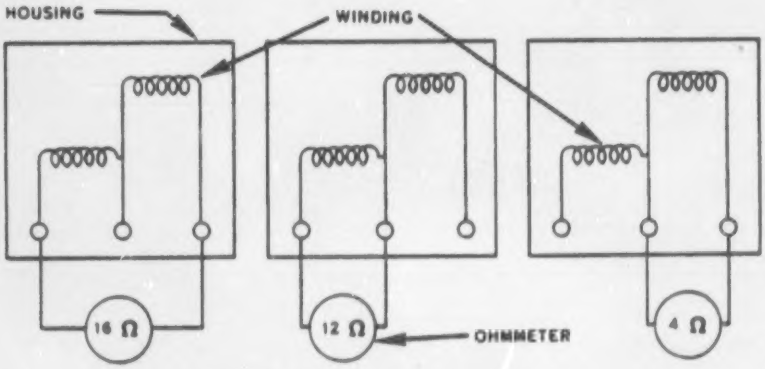

Figure 23. Taking Readings Across Terminals

- Memorize the following rules:
- The highest reading (1 and 3) is the RUN and START WINDINGS, figure 23, and this is read across the RUN and START TERMINALS. The remaining terminal (2) is the COMMON TERMINAL.

Highest reading is obtained by reading across the RUN and START terminals (this is the Run and Start Winding).

Middle reading is obtained by reading across the START and COMMON terminals (this is the Start Winding).

Lowest reading is obtained by reading across the RUN and COMMON terminals (this is the Run Winding).

- In this case, the terminals are as follows:

Terminal 1 is the Start Terminal.

Terminal 2 is the Common Terminal.

Terminal 3 is the Run Terminal.

Thermal Overloads

All hermetic compressors must have some protection against momentary overloads and voltage surges. Hot wire relays use the tension of the hot wire for this purpose. Current and potential relays require an external means of motor protection. This protection is provided by a unit known as a thermal or motor overload. This thermal overload, see figure 24, consists of a round bakelite casing containing a bimetal disk and a heater wire. The protector is usually connected in the common lead going to the compressor. All the electricity going to the compressor must pass through the protector.

The heater is designed to carry a given amount of current without getting hot. If the motor becomes overloaded and draws too much current, the heater will get hot. The heat affects the bimetal disc and causes it to break the circuit. As soon as the heater cools off, the bimetal disc will move back into position and complete the circuit again. This cycle will continue to repeat itself until the high current flow through the motor is reduced.

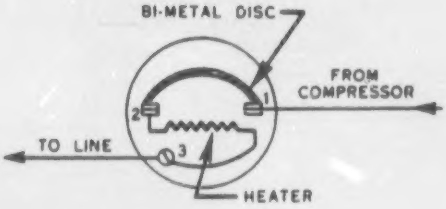

Figure 24. Thermal Overload

Thermal overloads cause very little trouble. However, they should always be replaced when replacing the starting relay. If a thermal overload appears to be faulty, it can be checked by the following procedures.

Unplug the unit and install a jumper wire across the thermal overload and plug the unit (turn unit on). If the unit operates, check the current flow through the jumper. If the current flow is not excessive, the thermal overload is faulty and must be replaced. If the current flow is excessive, unplug the unit immediately and check for the cause of the high current flow.

Some modern hermetic compressors come equipped with a bimetal thermal disc installed in the windings in the motor. This thermal disc aids in reducing motor burn-outs because it senses the temperature of the motor windings. The internal bimetal disc does not eliminate the need for an external thermal overload.

Only the power going to the compressor goes through the thermal overload. The condenser fan or any other unit must be connected on the line side of the thermal overload.

Clamp-On Volt-Ammeters

Most refrigeration servicemen prefer using the clamp-on instrument instead of the multimeter (due to the ease in checking amperage and voltage). Some of these clamp-on instruments also have an extra circuit for checking resistance.

PRINCIPLE OF OPERATION. Any time current passes through a conductor, a magnetic field is built up around the conductor. The higher the current flow, the stronger the magnetic field will be. When the jaws of the amprobe are clamped around the conductor, the magnetic field will cause the instrument to indicate the amount of current in the conductor.

STARTING HERMETIC COMPRESSORS

It is possible to start a hermetically sealed compressor without using a starting relay. Connect a plug-in cord to the common and run terminals as illustrated in figure 25. Momentarily, place an insulated jumper wire between the run and start terminals. The jumper wire must be removed as soon as the motor starts.

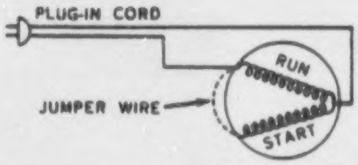

Figure 25. Jumper Wire System

A schematic of a pushbutton type starter cord is shown in figure 26. These starter cords come equipped with normal plug-in on one end and three alligator clips (for easy attachment on the compressor terminals) on the other end. The pushbutton switch is spring-loaded to the OPEN position.

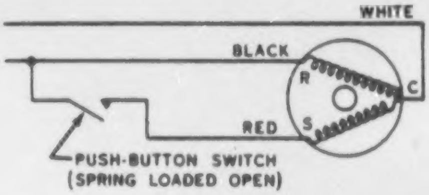

Figure 26. Schematic Pushbutton Starter Cord

A picture of a pushbutton starting cord is illustrated in figure 27. The alligator clips are color-coded as follows: Common - white, Run - black, and Start - red.

The main purpose of the starting cord is to check a malfunctioning starting relay. If the compressor will not start and you suspect that the relay is faulty, proceed as follows:

- Check the power at the relay.
- If there is electrical power coming into the relay, proceed to Step 3.
- Unplug the unit.
- Remove the relay.

- Install the white alligator clip on the common terminal.
- Install the black alligator clip on the run terminal.
- Install the red alligator clip on the start terminal.
- Plug-in the start cord.
- Push the start button.

CAUTION: The start button must not be held down more than a few seconds. If the compressor starts, the starting relay is faulty and must be replaced.

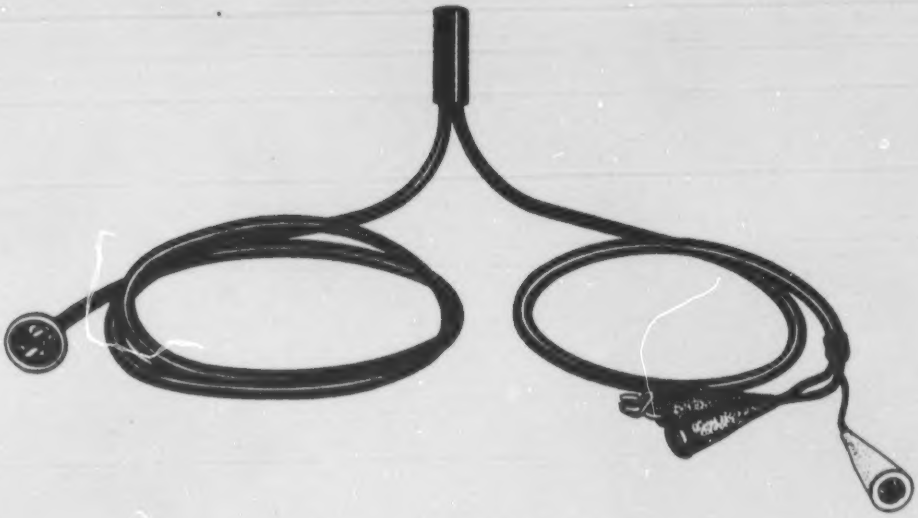

Figure 27. Pushbutton Starting Cord

Motor Start-Analyzer

These units are used for servicing hermetic compressors and have the capability to check continuity of the windings, check the compressor for grounded windings, starting of split phase or capacitor start compressors/motors, and when required they have the capability to reverse the rotation of a compressor/motor that is stuck (free this unit). See figure 28.

The analyzer test circuit is wired and protected for an intermittent load provided the unit being tested does not exceed the 30-amp, 115/230-volt, 60-cycle circuit.

Testing the Analyzer for Serviceability

Before taking the analyzer out of the shop for servicing a unit, perform the following operational check on the analyzer.

a. Plug the analyzer into outlet.

b. Turn the off/on switch to the on position.
c. Depress the pushbutton.
d. The pilot lamp should now burn. Analyzer is operational.
e. If the pilot lamp does not burn check the following:

  (1) The two 15-amp fuses.
  (2) Power supply
  (3) Lamp bulb (pilot) in the holder; it may be loose or burned out.

Figure 28. Motor Start-Analyzer

Using the analyzer to check the compressor/motor windings for continuity.

Plug the black plug into the number 2 jack and the red plug into the number 3 jack.

1. Plug the analyzer into the outlet.
2. Turn the off/on switch to the on position.
3. Using the corresponding color-coded clips, touch them to each pair of terminals (1 and 2, 1 and 3, and 2 and 3).
4. If the pilot lamp burns the windings are good.
5. If the lamp does not burn then there is an open in the windings.

Using the analyzer to check a compressor/motor for grounded windings.

1. Proceed as per steps 1 thru 3 (checking for open windings).
2. Using the two color-coded clips, touch one clip to a clean spot on the compressor/motor housing. With the other clip touch each of the terminals in turn.
3. If the pilot lamp does not light, there are no grounds.
4. If the pilot lamp burns, there is a ground.

Using the analyzer to start a split phase start compressor/motor.

1. After completing the two checks for opens and grounded windings, determine the run, start, and common terminals using the multimeter or the terminal color code chart attached to the analyzer (this chart is broken down by manufacturer).

Plug the jacks into the analyzer as follows:

When using the color-coded chart plug the jacks into the analyzer according to the color identification, then connect the corresponding colors to the properly color coded terminals on the compressor/motor (red to red, black to black, etc).

When checking a unit that is not included on the chart, or is not properly identified, identify the terminals using the multimeter, then plug the jacks into the analyzer as follows:

#1 Common
#2 Run
#3 start, split phase
#4 start, capacitor

and then connect the clips to the properly identified terminals on the compressor/motor, i.e., white to common terminal, black to the run terminal and red to the start terminal (split phase or capacitor).

After the wiring has been connected to the compressor/motor and the analyzer, plug the unit into an outlet, turn the off/on switch to the on position.

Depress the pushbutton, holding it in until the motor has reached its running speed (2/3 to 3/4 rated rpm), then release the pushbutton.

Using the motor start analyzer to start a capacitor start compressor motor.

Follow all of the procedures as used for split phase start with one exception: remove the jack from split phase start plug and place it into the capacitor start plug.

Turn on either one or both of the capacitor toggle switches depending on the rating of the capacitor in the system. (There are two capacitors wired in parallel, each is rated at 175 MFDs.)

Complete this operation by following steps 3 and 4 for split phase start.

Using the analyzer to reverse the rotation of a compressor/motor:

1. If the compressor/motor does not start (split phase or capacitor start) even though both capacitors were used, proceed as follows:

With both capacitor toggle switches in the on position, turn the off/on switch to the on position.

Hold the start switch in the on position and move the rocker switch handle. If the compressor/motor starts, release it and the start switch.

CAUTION: Do not attempt this rocking operation more than five (5) times in a fifteen (15) second duration.

SUMMARY

The field of hermetic units includes all types of refrigeration systems that use a hermetically sealed compressor and a capillary tube refrigerant control. These units include such things as domestic refrigerators, home freezers, window air conditioners, water coolers, ice cream cabinets, frozen food boxes and beverage coolers. Of all these units, the domestic refrigerator is the best known and the most widely used. The service and maintenance of hermetic units differ from normal systems the following ways:

Normally hermetic units will not have service valves. Therefore, to service these units, it is necessary to use a line-tap-valve, or access valve to connect the manifold gage assembly to the system.

All capillary tube systems require a very critical charge. All the liquid in the high side migrates to the low side (through the capillary tube) during the off cycle. If the system is overcharged, liquid refrigerant will be pulled into the compressor at the beginning of the next cycle.

Since all hermetic units are critically charge, even very small leaks cannot be tolerated. A leak of two ounces from a system that only holds eighteen ounces will effect the system's operation. Therefore, the leak testing procedures on hermetic units must be very thorough and exacting.

Open type motors do not use starting relays. Any work you do concerning starting relays will be done on hermetic units.

If a motor in a hermetic unit burns out, it will contaminate the complete refrigeration system. Cleanup after burnout is another service procedure that is peculiar to hermetic units.

By maintaining good workmanship practices and paying very close attention to details, the servicing of hermetic units is no more of a problem than any other refrigeration system.

QUESTION

1. Explain two specific characteristics of hermetic systems.
2. Name five units that are usually built as hermetic systems.
3. Where is a domestic refrigerator normally used?
4. List and explain the purpose of the three temperature areas in a domestic refrigerator.
5. Define insulation.
6. Name two types of insulation materials that are used on domestic refrigerators.
7. What precaution should be taken when working with Fiberglas?
8. List three advantages of using foamed plastic as an insulating material.
9. What is the purpose of a vapor barrier?
10. What is the purpose of the breaker strips?
11. What material is usually used to make breaker strips?
12. Explain the precautions to be taken when removing and replacing breaker strips.
13. Give the location and explain the purpose of a mullion heater.
14. Explain the construction features of a mullion heater.
15. Name four major components of a refrigeration system used in domestic refrigerators.
16. What is the most important advantage of hermetic compressors?
17. List three additional advantages of hermetic compressors.
18. List two disadvantages of hermetic compressors.
19. List three classifications of hermetic compressors.
20. List two types of hermetic compressors.
21. List two shaft mounting positions.
22. List three shaft designs.
23. What type compressors use the scotch yoke?
24. List three methods of lubrication of hermetic compressors.

25. List three methods of cooling the motor in hermetic compressors.

26. Explain why the motor in a hermetic compressor must operate in a low ambient temperature area.

27. Explain the principle of operation of the antislugging system.

28. List two types of condensers used on domestic boxes.

29. Explain the purpose of the oil cooler circuit on a domestic refrigerator.

30. What metal is usually used to make condensers?

31. List two types of evaporators used on domestic refrigerators.

32. What metal is usually used to make evaporators?

33. What type refrigerant controls are normally used on domestic refrigerators?

34. List and explain the two reasons for soldering the capillary tube to the suction line.

35. List the three malfunctions of thermostats.

36. Explain the symptoms of the three malfunctions listed in Question 35.

37. Name the two substances used to make door gaskets.

38. What is the purpose of the door gasket?

39. What is the most important factor to consider when installing a domestic refrigerator?

40. What three things concerning electrical power should you check before installing any electrical appliance?

41. List three methods of maintaining the required temperatures in low temperature boxes.

42. Which method (from Question 41) is used on "no-frost" refrigerators?

43. Explain the operation of a "defrost cycle" thermostat.

44. Name the two defrost systems used on domestic refrigerators.

45. List and explain the two advantages of the hot gas defrost system.

46. List and explain two disadvantages of the hot gas defrost system.

47. List three malfunctions of a hot gas defrost system.

48. List the symptoms of each of the malfunctions listed in Question 47.

9. List three advantages of the electrical defrost system.

50. List one disadvantage of the electrical defrost system.

51. List and explain three malfunctions of electrical defrost systems.

52. List three symptoms of a restricted or stopped up capillary tube.

53. List, in sequence, the three locations where you should check for a stopped-up capillary tube.

54. Explain the procedures for cutting a capillary tube.

55. Explain the procedures for installing a capillary tube in a piece of 1/4-inch copper tubing.

56. Name two things you need to know about a hermetic unit to be able to order a capillary tube.

57. What is the purpose of a process tube in a hermetic system?

58. What type of access valves are available for use on hermetic systems?

59. After one hour of use, the electronic leak detector must be turned off and allowed to cool for how long?

60. Name the methods of charging hermetic units.

61. List three types of starting relays.

62. Give one advantage and one disadvantage of current type relays.

63. Where are current relays normally used?

64. What is the advantage of the potential relay?

65. Where are potential relays normally used?

66. Where are hot wire relays normally used?

67. Find the common, start, and run terminals with the following ohmmeter readings:

    a. 1 to 2 = 4 ohms
       1 to 3 = 16 ohms
       2 to 3 = 12 ohms

    b. 1 to 2 = 18 ohms
       1 to 3 = 6 ohms
       2 to 3 = 24 ohms

68. Draw a schematic of a thermal overload.

69. In what lead is the thermal overload always located?

70. List the color code for the three leads on a starter cord.

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2. Data Book (Design) - American Society of Refrigerating Engineers
3. Service Handbook - Tecumseh
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WORKBOOKS 3ABR54530-V-1-P1 thru P8

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

DOMESTIC UNITS

January 1975

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This supersedes SG 3ABR54530-V-1 and WBs 3ABR54530-V-1-P1 thru P8, 1 October 1973
Copies of the superseded publication may be used until the supply is exhausted.

Dept of Civil Engineering Tng
Sheppard AFB, Texas

WB 3ABR54530-V-1-P1
21 January 1975

FAMILIARIZATION AND OPERATION OF DOMESTIC REFRIGERATORS

OBJECTIVE: To:

Locate and identify the major components of a domestic refrigerator.

Visually inspect a domestic refrigerator to determine its serviceability.

Operate a domestic refrigerator and visually inspect it to determine its operating condition.

1. Go to the refrigerator assigned you and locate each of the following components. Fill out the blanks as required.

a. Freezer Evaporator

(1) Type ______________________________

(2) Material ______________________________

b. Fresh Food Evaporator

(1) Type ______________________________

(2) Material ______________________________

(3) How do the freezer and fresh food evaporators differ?

____

____

c. Breaker Strips

(1) Purpose ______________________________

(2) Material ______________________________

d. Door Gasket

(1) Type ______________________________

(2) Material ______________________________

(3) What holds the door closed? ______________________________

____

e. Oil Cooler

Purpose ______________________________

F. Condenser

(1) Type ______________________________

(2) Material ______________________________

g. Capillary Tube

Give the exact location of the capillary tube. ______________________

____

h. Thermostat

Location of the thermal bulb ______________________

i. Filter-Drier

Give the exact location of the filter-drier. ______________________

____

j. Compressor. Type ______________ Size ______________

k. Drain trough

Give the exact location of the drain trough. ______________________

____

l. Drain line

The drain line runs from the ____________ to the ______________

m. Drain tray

What happens to the water that drains into the drain tray? ____________

____

____

2. Check the following and note any defects found:

a. Door hinge ______________________________

b. Outside shell ______________________________

c. Inside shell ______________________________

d. Shelving ______________________________

e. Vegetable trays ______________________________

f. Door gasket ______________________________

3. The unit should operate on ______________________________ volts.

4. Refrigerant to be used in this box is ______________________________.

5. Turn the thermostat off.

6. Plug in the refrigerator.

7. Does the cabinet light work? ______________________________

8. Depress the door switch. Does the light go out when the door switch is depressed?

____

9. Turn the thermostat to the midrange.

10. Did the compressor start? ______________ Yes ______________ No

11. Place a thermometer in the freeze compartment.

12. Allow the unit to operate about 1 hour and check the temperature. Temperature reading ______________________________

13. The evaporator pressure is ______________________________

14. Feel the suction line. It is ______________________________

15. Feel the discharge line. It is ______________________________

16. Feel the condenser. Which is the hottest - the top or bottom? Explain.

____

____

____

____

17. Unplug the refrigerator and trace the flow of refrigerant.

18. Have the instructor check your work.

Checked by ______________________________

WB 3ABR54530-V-1-P2

TROUBLESHOOTING ELECTRIC DEFROST

OBJECTIVE: This project will aid you in becoming familiar with the principles of operation of electric defrost system, malfunctions, and maintenance required.

1. With the aid of the Electrical Defrost Schematic (Figure 1), explain why the following conditions occur.

   a. Defrost heaters stay on too long ______________________________

   ____

   b. The unit is defrosting, but the water will not drain ______________________

   ____

   c. List three malfunctions that would keep the unit from defrosting

   (1) ____

   (2) ____

   (3) ____

   d. The meter reading at terminals 2 and 3 is applied voltage, but the compressor will not run ______________________________

   e. The meter reading at terminals 4 and 8 is applied voltage, but the system will not defrost ______________________________

   f. The meter reading at terminals 1 and 3 is applied voltage, but the timer is not running ______________________________

   g. The meter reading at terminals 9 and 10 is applied voltage. The box temperature is 70° ______________________________

   h. The resistance reading between terminals 14 and 16 is 8 ohms. The reading between terminals 15 and 16 is infinity ______________________________

   ____

Checked by ______________________
Instructor

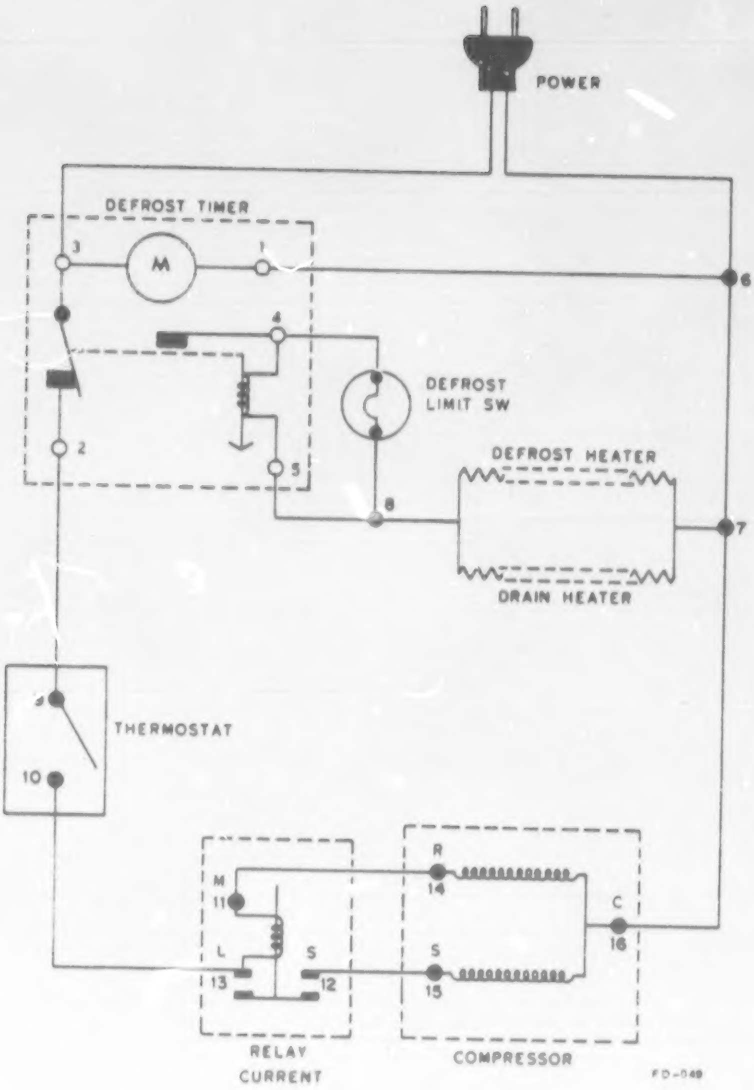

POWER
DEFROST TIMER
3
M
1
6
4
DEFROST LIMIT SW
2
5
DEFROST HEATER
8
7
DRAIN HEATER
9
THERMOSTAT
10
M
11
L
13
S
12
R
14
C
16
S
15
RELAY CURRENT
COMPRESSOR
FD-049

Figure 1., Electrical Defrost

INSTALLING A CAPILLARY TUBE

OBJECTIVE: This project will give you practical experience in installing a capillary tube in a piece of copper tubing, and installing an access valve.

1. Cut a 5-inch length of copper tubing and a piece of capillary tubing (from stock).

   NOTE: The capillary tubing should be cut with a file.

2. Ream and dress the copper tubing.

3. Use a piece of emery cloth and clean the inside of the tubing. Clean an area 1/2 to 3/4 inch deep.

4. Use a piece of emery cloth and clean the outside of the capillary tube. Clean an area around the tube approximately 1 1/2 to 2 inches back from the end.

5. Insert the capillary tube in the copper tubing.

   NOTE: The capillary tube should be inserted in the copper tubing 1 1/2 inches.

6. Explain why the capillary tube should be inserted so far in the copper tubing.

   ____

   ____

7. Use a pair of pliers and crimp the copper tubing securely around the capillary tube.

   CAUTION: Make sure you do not kink or collapse the capillary tube.

8. Apply flux to tubing.

9. Use an acetylene torch and silver solder the connection.

   a. Is the capillary tube restricted? ______________________________

   b. Was too much solder used? ______________________________

10. Install an access valve in the other end of the copper tubing.

    NOTE: Be sure to remove valve core before soldering.

11. Crimp and solder the end of the capillary tube.

12. After sufficient cooling time, replace valve core.

13. Connect a manifold gage assembly to the access valve and charge to 60 psi.

14. Leak test all connections.

15. Were there any leaks? ______________________________

16. Remove access valve.

Checked by ______________________

Instructor

CHARGING A HERMETIC UNIT

OBJECTIVE: This project will give you practical experience in evacuating and charging a hermetic unit, and leak testing a hermetic unit.

1. Connect the manifold gage assembly to the access valves.

   NOTE: Make sure you use the correct type charging lines.

2. Charge the system to 60 psi.
3. Leak test the system.
4. If there are no leaks, purge the refrigerant to the atmosphere.

   NOTE: Make sure the work area is well ventilated.

5. Evacuate the system to a 29-inch vacuum.
6. Break the vacuum with refrigerant and raise the pressure to 5 psi.
7. Purge the refrigerant to the atmosphere.
8. Evacuate the system to a 29-inch vacuum.
9. Break the vacuum with 5 psi of refrigerant.
10. Evacuate and proceed with the charging.

WEIGHTED METHOD OF CHARGING A DOMESTIC REFRIGERATOR

1. Fill the charging station with refrigerant as required by data plate.
2. Using the charging station, charge the unit.

   NOTE: Allow refrigerant vapor into both the low and high sides.

3. Check the unit after one hour's operation.
   a. Low side pressure ____________________
   b. High side pressure ________ ____________________
   c. Condition of suction line ____________________
   d. Temperature of evaporator ____________________

NOTE: Head pressure will usually run high until unit has time to pull down. Suction pressure may be in a vacuum.

4. Check unit after two hours operation.

   a. Low side pressure ______________________

   b. High side pressure ______________________

   c. Condition of suction line ______________________

   d. Temperature of evaporator ______________________

Checked by ______________________

Instructor

DIRECT METHOD OF CHARGING A DOMESTIC REFRIGERATOR

1. Open the low side manifold valve and charge until the suction pressure remains approximately 5 psi.

2. Close the manifold valve and check the pressure.

   NOTE: As discussed in class, more or less refrigerant may be needed for correct charge.

3. After reaching the required pressures, allow the unit to operate.

4. Check the unit as follows and record the results.

   a. After one hour's operation.

      (1) Low side pressure ______________________

      (2) High side pressure ______________________

      (3) Condition of the suction line ______________________

      (4) Temperature of the evaporator ______________________

   b. After two hour's operation

      (1) Low side pressure ______________________

      (2) High side pressure ______________________

      (3) Condition of the suction line ______________________

      (4) Temperature of the evaporator ______________________

5. A frosted suction line indicates ______________________

6. Purge refrigerant from the refrigerator a little at a time. (This process is normally accomplished over a long period of time.)

7. When the suction line no longer has frost or condensation on it, have the instructor check your work.

8. Explain to the instructor how the air flows in the domestic refrigerator assigned to you.

9. Explain to the instructor how the refrigerant flows through the system.

Checked by____________________________

Instructor

WIRING STARTING RELAY CIRCUITS

OBJECTIVE: This project will aid you in becoming familiar with the principles of operation of starting relays and give you practical experience tracing the current flow through starting relays.

1. Study the components in figures 2, 3, 4, 5, and 6.
2. Start at the plug-in and complete the electrical circuit through each of the relays.
3. Have the instructor check your diagram before going to trainer.

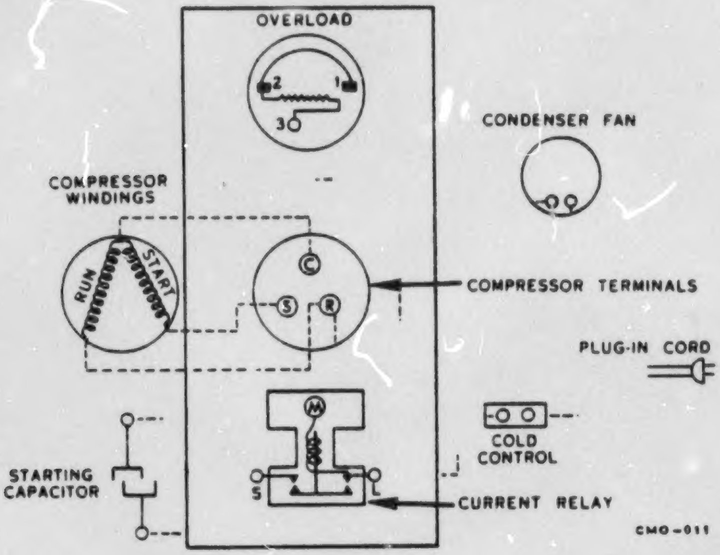

OVERLOAD
2
1
3
CONDENSER FAN
COMPRESSOR WINDINGS
RUN
START
C
S
R
COMPRESSOR TERMINALS
PLUG-IN CORD
M
COLD CONTROL
S
L
STARTING CAPACITOR
CURRENT RELAY
CMO-011

Figure 2 . Current Relay

After the instructor checks your diagram, go to the current relay trainer and wire the trainer. Have the instructor check the wiring before power is turned on.

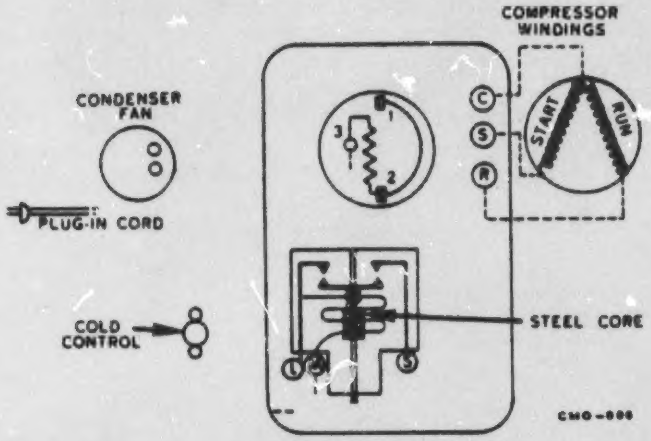

COMPRESSOR WINDINGS
CONDENSER FAN
C
S
R
START
RUN
1
2
3
PLUG-IN CORD
COLD CONTROL
STEEL CORE
L
M
S
CMO-000

Figure 3 . Current Relay (Spencer)

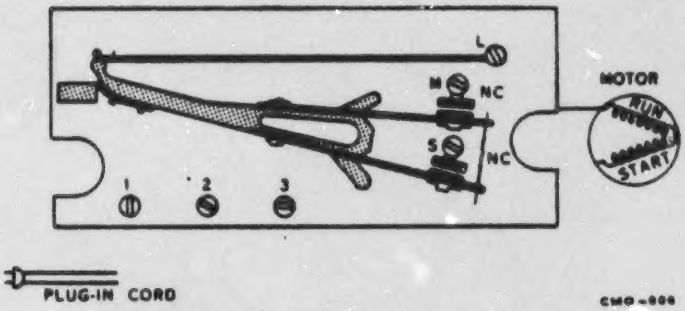

L
M
NC
S
NC
MOTOR
RUN
START
1
2
3
PLUG-IN CORD
CMO-000

Figure 4. Hot Wire Relay

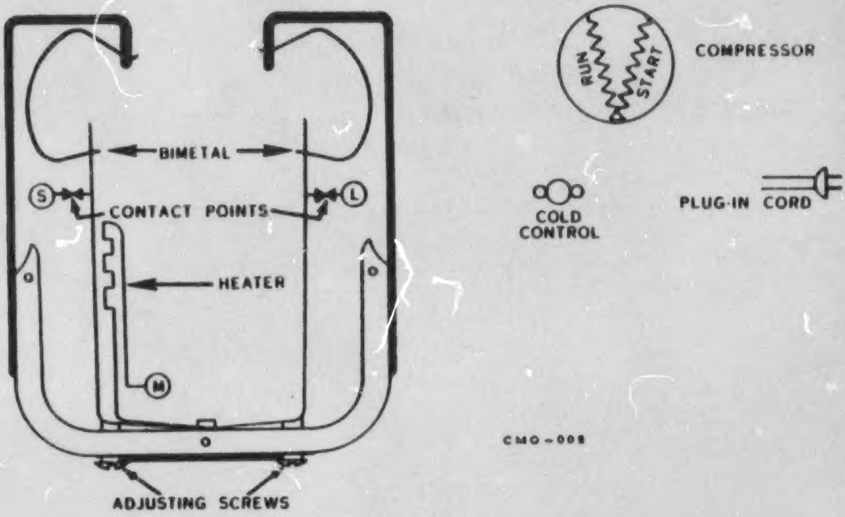
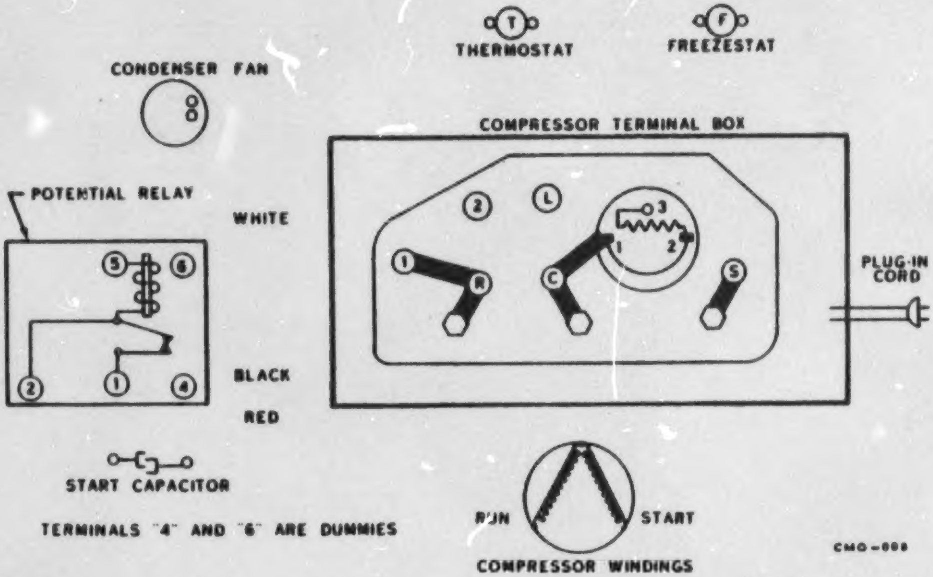

BIMETAL
S
L
CONTACT POINTS
HEATER
M
ADJUSTING SCREWS
RUN
START
COMPRESSOR
COLD CONTROL
PLUG-IN CORD
CMO-008

Figure 5 . Thermal Relay

287


THERMOSTAT
FREEZESTAT
CONDENSER FAN
COMPRESSOR TERMINAL BOX
POTENTIAL RELAY
WHITE
PLUG-IN CORD
BLACK
RED
START CAPACITOR
TERMINALS "4" AND "6" ARE DUMMIES
RUN
START
COMPRESSOR WINDINGS
CMO-008

After the Instructor checks your drawing, go to the potential relay trainer and wire it. Have the instructor check the wiring before turning power on.

Figure 6. Potential Relay

Procedure: Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

PREOPERATIONAL CHECK:

1. Remove all jewelry prior to working on trainers.
2. Powerline should be unplugged.
3. Master switch must be in the OFF position.
4. Place all trouble switches in the ON position.
5. Check for frayed or loose wiring.
6. Discard leads that are not properly insulated.
7. Check refrigerant tubing for evidence of leaks.
8. Check fan for freedom of rotation.

OPERATIONAL SAFETY CHECK:

1. Using diagram in figures 2, 3, 4, 5, or 6, wire the relay.
2. Leads should be installed securely.
3. Have the instructor check the wiring before power is turned on.
4. Make corrections as required.
5. Plug in power cord and turn on master switch.
6. Observe panel light for power indication.
7. Do not remove leads while unit is running.

POSTOPERATIVE CHECK:

1. Shut master switch OFF.
2. Unplug powercord.
3. Remove leads and place in storage drawer.
4. Have the instructor check your work.

Checked by ______________________________

Instructor

28

DETERMINING TERMINAL ARRANGEMENT

OBJECTIVE: To use the multimeter to determine the resistance of the windings in a hermetic compressor; check compressor for opens and grounds; determine the run, start and common terminals; trace refrigerant and airflow through a two temperature refrigerator; and troubleshoot the electrical defrost system.

1. Obtain a multimeter from the tool cabinet.

2. Select a hermetic compressor as directed by the instructor.

3. Set up and check the multimeter to read resistance.

4. Draw a picture of the terminal arrangement.

5. Check the winding for opens
   a. What did the meter read? ______________________________

   b. What does this reading mean? ______________________________

6. Check the windings for grounds.

   a. What did the meter read? ______________________________

   b. What does this reading mean? ______________________________

7. Number the terminals in your drawing 1, 2, and 3.

8. Use the multimeter and take reading across each set of terminals. Record the reading in the spaces provided below:

   a. 1 and 2 = __________

   b. 1 and 3 = __________

   c. 2 and 3 = __________

9. The highest reading is the __________ and __________ terminals.

10. The lowest readings are the __________ and __________ terminals.

11. The middle reading is the _____ _____ and __________ terminals.

12. Why must the middle and lowest readings equal the highest reading? __________

____

299

290

13. Label the terminals in your drawing R, S, and C, representing run, start, and common.

Checked by____________________________

Instructor

300

TROUBLESHOOTING HERMETIC UNITS

OBJECTIVE: This project will give you practical experience checking and troubleshooting starting relays.

INTRODUCTION: Normally you will use a motor start-analyzer to troubleshoot starting relays. However, if a motor start-analyzer is not available it will be necessary to use other types of testing equipment.

CHECKING A STARTING RELAY (Using a plug-in cord and jumper wire).

Condition: Compressor will not start. The switch is on and electricity is available at the starting relay.

Possible Troubles:

1. Starting relay faulty.
2. Compressor burned out.

Checking Procedures:

1. Remove the electrical connectors at the compressor terminals.
2. Determine the common, run and start terminals. (Use WB 3ABR54530-V-1-P4.)
3. Connect the plug-in cord to the "common" and "run" terminals.
4. Plug in the cord.
5. Momentarily place a jumper wire between the "run" and "start" terminals. Make sure the jumper wire is insulated.

   CAUTION: The jumper wire must not be left in place more than one second.
6. Did the compressor start? ______________________________
7. What would happen if you placed the jumper wire between the "common" and "run" terminals? ______________________________

   ____
8. Place a clamp-on voltammeter around one of the electrical conductors.
9. What is the amperage draw? ______________________________
10. What is the amperage draw on the data plate? ______________________________

11. An excessive amperage draw will indicate:

    a. ____

    b. ____

    c. ____

12. The following conditions can be determined from the information gained in the above tests.

    a. ____

    b. ____

    c. ____

13. Unplug and remove the plug-in cord.

14. Replace the electrical connection on the compressor terminals.

15. Have the instructor check your work.

Checked by ________________________

Instructor

CHECKING A STARTING RELAY (Using a pushbutton starter cord.)

NOTE: All refrigeration specialists should have a pushbutton starter cord. It is much handier and less dangerous than using a plug-in cord and jumper wire.

Conditions and Possible Troubles:

The same as with the plug-in cord and jumper wire.

Checking Procedures:

1. Remove the starting relay.
2. Connect the terminals of the starting cord to the compressor.

    a. "Red" lead to the ________________________ terminal.

    b. "Black" lead to the ________________________ terminal.

    c. "White" lead to the ________________________ terminal.

3. Plug in the starting cord.
4. Push the pushbutton.

5. Did the compressor start? ______________________________

6. This indicates the relay is ______________________________

7. Draw a schematic of a compressor and pushbutton starter cord. Label the compressor windings, terminals, electrical leads, and starting switch.

8. Use the clamp-on voltammeter and check the voltage drop between the unit and ground.

9. What is the purpose of Step 8? ______________________________

____

____

10. Unplug the starting cord.

11. Replace the starting relay.

12. Replace all your tools and equipment.

Checked by ______________________________

Instructor

USING MOTOR START ANALYZER

OBJECTIVE: This project will give you practical experience using the motor start analyzer to check the motor windings for continuity, check for a grounded winding in a hermetically sealed unit, and start hermetically sealed units.

FAMILIARIZATION WITH ANALYZER

1. Locate each of the following parts of the analyzer:
    a. Hermetic unit terminal color chart.
    b. Test lamp for checking continuity.
    c. Pushbutton for applying power to the analyzer.
    d. Rocker switch for reversing the motor.
    e. Bank of capacitors and switches.
    f. Three clips for connection to a sealed unit.
    g. Plug for connection to an electrical outlet.
2. Go to the hermetically sealed unit assigned you and complete the following tests.

TEST MOTOR WINDINGS FOR CONTINUITY

1. Insert any two (2) of the plugs in jacks Number 2 and 3 on motor-start analyzer.
2. Connect the analyzer to a source of electrical power.

    NOTE: To check power to the motor start analyzer, turn power switch on and depress pushbutton switch. If power is available, the test lamp on the analyzer will light.

3. Remove wiring from the refrigeration unit. Refer to color chart and locate the "start," "run," and "common" terminals. (Use bench compressors.)
4. Place one test clip on the "common" terminal. Touch the other clip to the "start" terminal, if the test lamp on the analyzer lights, the starting winding is good.
5. Repeat the above test using the "common" terminal again and touching the second lead to the "run" terminal.

    The above tests indicated____

    ____

TEST FOR GROUNDED WINDINGS

1. Set up motor start analyzer by inserting any two plugs into jacks Number 2 and 3.
2. Clip one lead to the motor-compressor case. Make sure it is making good contact.
3. Turn power switch ON.
4. Take the other clip and touch the "run," "start," and "common" terminals successively. If the lamp does not light, the windings are not grounded to the motor-compressor case.

   The above test indicated that the winding(s) ______________________________

   ____

START THE UNIT WITH THE ANALYZER

1. Plug the analyzer into a power source and press the pushbutton. The lamp should light giving an indication of power.
2. Disconnect all leads from the refrigeration unit.
3. Connect the clips to terminals corresponding in color to the leads.
4. Refer to the color chart and insert the plugs into the analyzer in accordance with the color chart.
5. Remember, when you are starting the unit with the analyzer you are bypassing the starting relay, and with capacitor start motors, you must use the capacitor in the motor start analyzer.
6. Turn power switch ON, then press the pushbutton and release it. This is taking the place of the starting relay and must not be held down too long.
7. Did the unit start? ____________ If not, why? ______________________

   ____

REVERSING THE MOTOR TO BREAK LOOSE A STUCK COMPRESSOR

CAUTION: DO NOT PERFORM THE FOLLOWING TEST UNLESS THE COMPRESSOR IS STUCK!

1. Place the three color-coded test cord plugs in the jacks according to the color chart.

2. Place the start winding test lead into the "cap-start" jack.

3. Place both capacitor switches in ON position.

4. Turn power switch ON.

5. Hold the pushbutton down and at the same time operate the handle of the rocker switch.

NOTE: The rocking operation should not exceed five times in fifteen seconds.

6. When the motor rotor breaks free release the rocker-switch handle first and then release the pushbutton.

7. Have the instructor check your work.

Checked by ______________________

Instructor

8. Clean up the area and replace all tools.

ATC-SHEPPARD AFB TEX. 79-1089

STUDY GUIDE 3ABR54530-V-2

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

COMMERCIAL UNITS

January 1975

SHEPPARD AIR FORCE BASE

11-7

Designed For ATC Course Use

DO NOT USE ON THE JOB

Department of Civil Engineering Training
Sheppar AFB, Texas

SG 3ABR54530-V-2
21 January 1975

COMMERCIAL UNITS

OBJECTIVE

To help you in learning the purpose, principle of operation, servicing, maintenance, and troubleshooting of various types of commercial refrigeration units.

INTRODUCTION

The refrigeration field is divided into three major areas: domestic, industrial, and commercial. There is no clear-cut dividing line between any of these areas. A unit that would normally be classified in one area may be used in either of the other two areas.

MAJOR AREAS IN REFRIGERATION FIELD

Domestic

This area is made up of units that use low-starting torque compressors and capillary tube refrigerant controls. They are normally used in the home. In the past, a refrigerator was considered domestic if it was 16 cubic feet or smaller in size. Any refrigerator larger than 16 cubic feet was classed as a commercial unit. This is no longer true. Some manufacturers are producing domestic cold storage-refrigerator boxes with a total volume of more than 16 cubic feet.

Industrial Units

These units are used in factories and for equipment cooling. They are very large, normally requiring at least one attendant. These units are used in the following applications:

- Ice manufacture
- Skating rinks
- Equipment cooling
- Refrigerated warehouses
- Food freezing
- Precooling vegetables and milk

Commercial

The commercial area is made up of units used in businesses. These systems normally use high-starting torque compressors and normally thermostatic expansion valves. Commercial units include:

- Cold storage boxes
- Reach-in boxes
- Walk-in refrigerators
- Soda fountains
- Water coolers
- Florist cabinets
- Display cases
- Ice cream cabinets
- Beverage coolers
- Ice makers

This supersedes SG3ABR54530-V-2 and WB 3ABR54530-V-2-P1 thru P7, 15 October 1973
Copies of the superseded publication may be used until the supply is exhausted.

The Air Force utilizes industrial units in the following applications:

Ice plants (overseas only)

Refrigerated warehouses

Photography

Blood processing

WALK-IN BOXES. These refrigerators are used in mess halls, food stores, and commissaries to store perishable products.

There are two types of walk-in boxes: the built-in and sectional. The built-in is made as a room and is a permanent part of a building. The sectional is manufactured in pieces to be assembled on any site and operated. It may be disassembled and moved when necessary. These sections (see figure 1) are usually handled by two men and small enough to pass through a normal sized door.

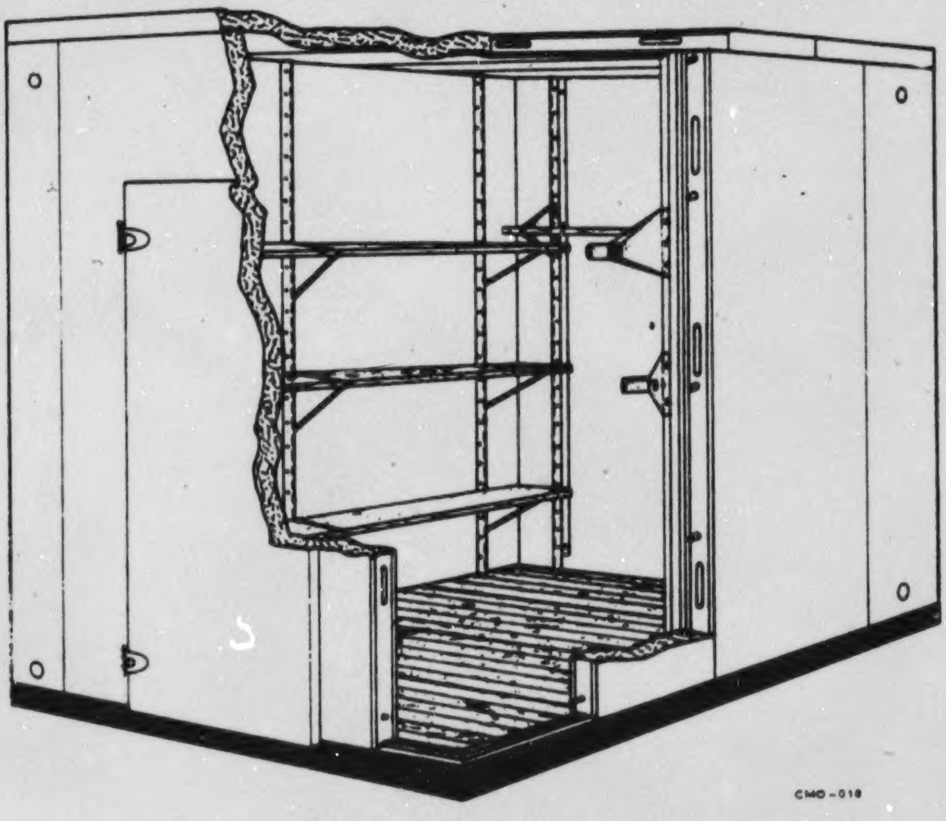


Figure 1. Sectional Walk-in Refrigerator

Condensing Units. Some walk-in boxes use a plug-type self-contained refrigeration system that includes the evaporator, compressor, condenser, and all the accessories and electrical components. These units are bolted in place through a hole in the side of the box with the evaporator inside and the condensing unit outside.

Most walk-in boxes use a remote condensing unit. These units may be hermetic, semihermetic, or open-type compressors with either air, water, or evaporator type condensers.

Insulation. Any substance that will retard the flow of heat may be used for insulating purposes. There is no perfect insulation. If the temperature difference is high enough and the transfer time long enough some heat will pass through any material of any thickness.

Insulation is used to:

Retard heat flow.
Prevent water condensation on cold pipes, ducts, and surfaces.
Reduce temperature fluctuation within the refrigerated space.
Stop water vapor transmission.
Reflect heat and light.
Provide soundproofing.
Provide a fire barrier.

Characteristics of Insulating Materials. A good insulating material should possess as many of the following characteristics as possible:

Low Thermal Conductivity ("K" Factor). The "K" factor is the amount of heat that will pass through 1 square foot of insulating material 1-inch thick in 1 hour with a temperature difference of 1° Fahrenheit. It becomes very obvious that the lower the "K" factor is, the less heat that will flow through the material.

The "K" factor varies with different materials. An example of this would be yellow pine, 1 Btu will travel through 1 square foot of yellow pine in 1 hour with a temperature difference of 1°F. The "K" factor of yellow pine being 1.

Settling of Insulation. Some insulation materials can settle enough to make a four- or five-inch space at the top of it and the refrigerator in a four- or five year period. Therefore, loose-type materials should not be used in vertical walls.

Moisture Resistance. When insulating materials get wet heat flows through into the refrigerated space freely. Moisture causes some materials to swell. This could cause enough pressure to warp or otherwise damage a wall. If the moisture freezes in the insulation expanding ice crystals may damage the walls.

Low Specific Weight. The lighter an insulation is the more desirable it is if it possesses the other qualities.

Vermin Resistance. Rats, mice, other small animals and termites can damage some insulating materials beyond repair.

Fire Resistance. Materials used as insulation should not be easily burned.

Major Types of Insulating Materials. Construction materials, such as wood, brick and building blocks, are not considered insulating materials. However, many walk-in boxes are constructed of wood. Therefore, both the inside and outside wall must be considered when figuring heat transfer rate.

Rockwool. Rockwool comes in either batts or bags. Batts are usually made by enclosing a layer of rockwool (1 to 4 inches thick) within an asphalt-impregnated kraft paper envelope. This batt is then stapled between the studs in the wall. Normally, rockwool is used for air conditioning only.

Fiberglas. Fiberglas is used in air conditioning as well as all types of refrigeration equipment. A low density Fiberglas is used in air conditioning while a high density material is used in low temperature refrigeration units.

Plastic foam. This is the lightest and best insulating material in use today. It is made of various densities for a variety of applications. It is also more expensive than Fiberglas but less is needed to do the same job. Plastic foam is available in board form or it may be poured and foamed in place. One disadvantage of plastic foam is it will burn. Therefore, it cannot be used as a fire barrier.

Reflective Insulation. Heat can be reflected the same way as light to provide what is called a reflective barrier. By placing a bright shiny surface between the structural wall and the insulation, much heat that would normally enter the room is reflected out. When the reflective barrier is used as a vapor barrier it must be installed toward the surface that has the highest water vapor pressure. Normally, aluminum foil is used as a reflective insulation. Bright, shiny plastics are also used.

Vapor Barrier. Water vapor is low pressured steam in the air, and it has a specific pressure. In accord with its temperature this pressure acts as air pressure. The high vapor pressure outside where it is hot will always try to enter an area that is cold because the vapor pressure is lower. Materials used to slow vapor transmission include plastics, aluminum foil, tar, asphalt, moistureproof paints, and asphalt impregnated paper.

REFRIGERATION SYSTEMS. Most commercial refrigeration systems of 3 hp or more have condensing units which use a semihermetic or open type compressor. The condensing unit may be remotely installed, of the plug-in type, or self-contained.

Compressors. The compressors are reciprocating type and some have oil pumps. Attention must be given to the direction of compressor rotation as some oil pumps only pump oil in one direction.

Condensers. The three types of condensers used are forced convection (air), evaporative cooled (water and air), and water cooled (water). The forced convection type consists of a fin and tube coil with a fan. The evaporative condenser has a sump tank to hold the water, a water pump to circulate the water, and a fan to move the air. When the head pressure is low the fan should be cycled off. Never cycle the water pump to control the head pressure. A water-cooled condenser on this type application is usually a once through system. That is, tap water is circulated through to the condenser and to the drain (water is not reused). The head pressure is controlled by a water regulating valve. This valve should be installed in the water inlet line.

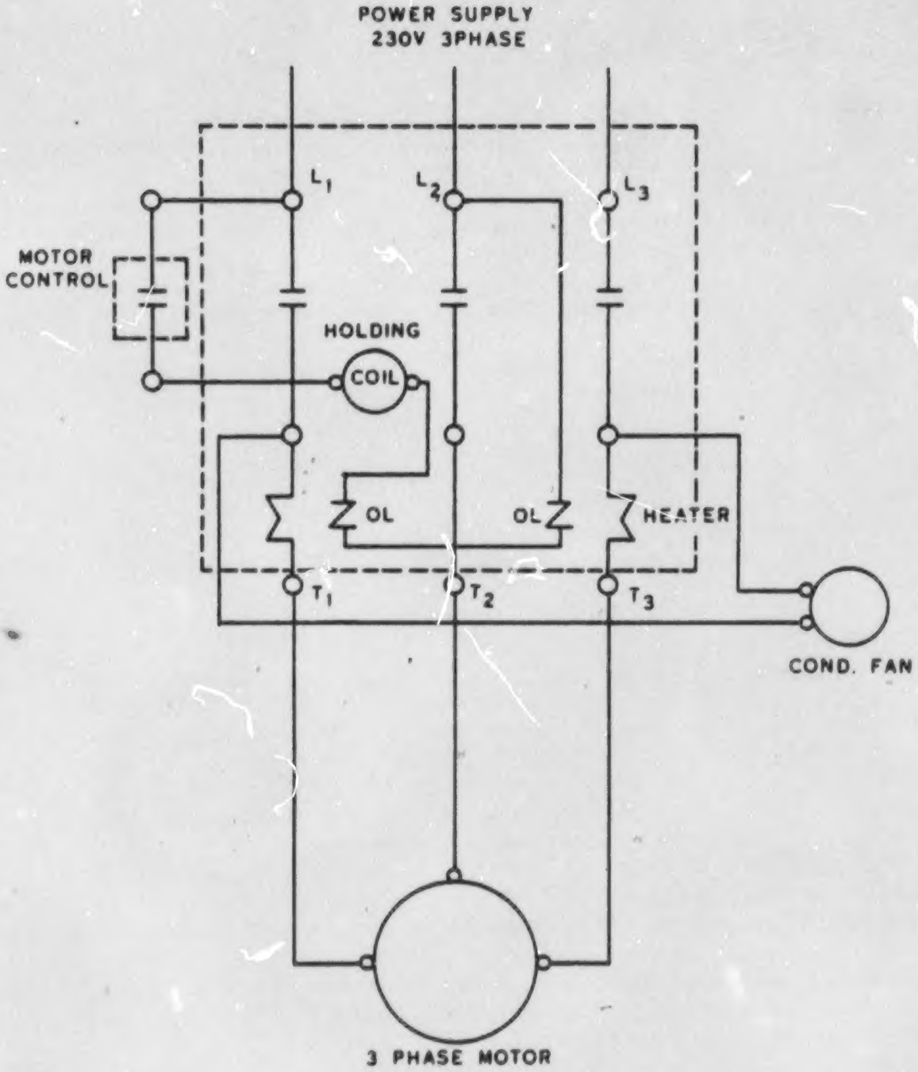

POWER SUPPLY
230V 3PHASE
L1
L2
L3
MOTOR CONTROL
HOLDING
COIL
OL
OL
HEATER
T1
T2
T3
COND. FAN
3 PHASE MOTOR
EH-074

Figure 2. Three-Phase Motor Starter

Driers. Driers are installed to remove moisture and acids from the refrigerant. They should be installed inside the refrigerated space when possible.

Solenoid Valves. Solenoid valves are installed in the liquid line on some refrigerators. They are used as an automatic shutoff valve that stops the flow of refrigerant.

Metering Device. Most commercial refrigerators use a T. E. V. Some small systems use the capillary tube. The gas charge and pressure limiting T. E. V. offer motor protection because it will not let the suction pressure go above the MOP of the valve. If a liquid charge valve without a pressure limiter is used, a solenoid valve should be installed (see para above) to prevent the refrigerant from migrating to the evaporator on the off cycle. Distributors are sometimes used on the outlet of the valve to decrease the pressure drop in the evaporators. The distributors feed in two or more places making one large evaporator into two or more smaller evaporators.

Evaporators. The two evaporators most commonly used are plate, and fin and tube. The plate uses natural convection to circulate the air. Fin and tube coils can be natural convection or forced convection.

ELECTRICAL SYSTEM. Most of the smaller condensing units use relays (potential and current) to start the motors but on larger motors and 3-phase motors a motor starter (line starter) must be used. Without the use of a line starter on a three-phase motor, an open in one of the power legs would cause the motor to single-phase and burn up.

Motor Starter. (See figure 2.) Power is connected to L_1, L_2, and L_3. The motor or load is connected to T_1, T_2, and T_3. If the N.O. (normally open) contacts were closed the motor would run. To get these contacts to close, the coil in the motor starter must be energized. This is accomplished by bringing power from L_2 through the two N.C. (normally closed) contacts in the O. L. (over loads) to one side of the coil. The other side of the coil goes through the motor control to L_1, now when the contacts in the motor control close the coil will energize, closing the contacts in the motor starter to run the motor. If the motor draws excessive amperage, the heaters will overheat the O. L., opening its contact points and deenergize the coil. The contacts in the motor starter will now open, stopping the motor. Note that the condenser fan is connected above the heaters because the heaters are sized for the compressor motor only.

DEFROST SYSTEMS. Ice is a good insulating material which is an advantage in some cases, but is a hindrance on evaporator surfaces. Therefore, anytime the temperature of the conditioned space is below 32°F, some method for defrosting the evaporator is necessary.

Formerly, walk-in boxes, refrigerated warehouses, and locker plants used plate or bare coil evaporators. The defrosting was accomplished by manually scraping the accumulated ice from the evaporator surface. To defrost cold storage boxes and ice cream cabinets, the food products were removed and the boxes allowed to warm up enough to melt the ice. The use of forced convection evaporators in below freezing applications requires that some automatic defrost system be employed.

Several different defrost methods have been used, each with its own advantages and disadvantages.

Water Defrost System. Figure 3 illustrates the water defrost system. The equipment includes a spray header, drain pan, two-way valve, necessary piping, and in some cases, warm water tank and pump. When the valve is in the normal position no water can can go to the spray chamber but any water in the pipes can flow to the drain. This prevents the freezing of water in the spray chamber or pipes. By placing the valve in the defrost position, water is allowed to flow to the spray chamber. The water then flows down over the evaporator melting the ice. After the defrost is completed the valve is returned to the normal position. It is necessary that the compressor and evaporator fan be turned off during the defrost period.

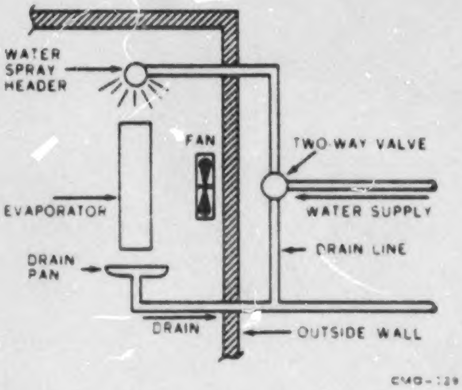


Figure 3. Water Defrost System

We have used a manual system to explain the operation of the water defrost system. However, there are few manual defrost systems in operation. Most defrost systems are automatic. A timer is usually incorporated in the system that turns the compressor and evaporator fan off, opens the defrost water valve and in some cases turns the water pump on. The water sprays over the evaporator for one to 15 minutes, depending on the adjustment. There is a one- to five-minute drain off period after the water valve is closed and the pump turned off before the compressor and evaporator fan are turned on. This prevents water freezing or being blown over the stored product. After the drain period the timer returns the system to normal operation.

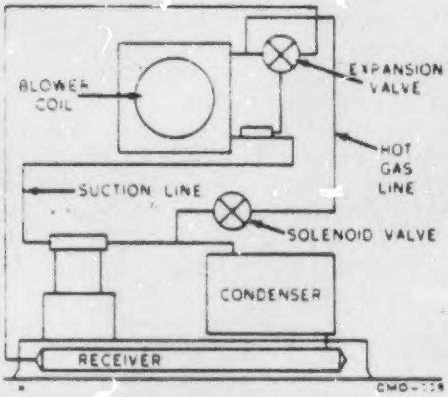


Figure 4. Simple Hot Gas Defrost System

Hot Gas Defrost System. A simple hot gas defrost system is illustrated in figure 4. The system has a bypass line containing a solenoid valve installed between the hot gas line and the evaporator. A timer turns the compressor off and opens the hot gas solenoid valve. The hot gas in the condenser flows to the evaporator and melts the frost. This system works very well as long as there is enough hot gas in the condenser to complete the defrost. If the condensing unit operates in a low ambient temperature area there may not be enough hot gas to completely defrost each cycle. In this case the evaporator will freeze up and have to be manually defrosted.

Electrical Defrost System. An electrical defrost system has some advantages and disadvantages that the hot gas system does not have.

1. Advantages:

   a. Provides a positive means of defrosting

   b. Is simple to understand and troubleshoot

2. Disadvantages:

   The main disadvantage is the cost. On small units, 2 hp or less, the cost is not excessive. However, on larger systems, 10 hp or more, it is usually more economical to use some type of hot gas defrost.

A typical electrical defrost consists of the following major components:

a. Finned forced convection evaporator

b. Electrical heating element. The heating element is located in the evaporator or as near the refrigerant coil as possible.

c. Defrost timer.

d. Time delay in the fan circuit

e. Electrically heated drain pan

A typical electrical defrost system is illustrated in figure 5.

When the predetermined setting on the defrost timer is reached the pump down solenoid valve in the liquid line will close and the unit will pump down and cycle off by the low pressure motor control. At the same time, the timer setting is reached the evaporator fans will be turned off and the heating elements will be turned on. When the evaporator temperature reaches approximately 35°F, the defrost thermostat stops the flow of current to the heaters by energizing the reset solenoid which puts the unit back in normal operation. If the evaporator temperature has not reached 35°F before the end of the defrost time setting is reached, the timer will stop the current flow to the heaters and put the unit back in normal operation. When the unit returns to normal operation after a defrost cycle, the evaporator fans will not run immediately. The thermostat in the fan circuit keeps the fans off until the evaporator reaches a predetermined temperature. This allows the water time to drain off the evaporator into the drain pan. This also keeps the fan from blowing water into the conditioned space. The hot liquid line may be soldered to the drain line to keep the drain from freezing.

DEFROST TIMERS. Three defrost timers used on commercial refrigerations systems are:

Time initiated-time terminated. This is the cheapest timer. It is often used on chillers to guarantee at least one complete defrost every 24 hours. Set the timer to turn the compressor off for a period of one hour when the box is not being used. The main disadvantage of this type timer is each defrost cycle must be the same length, regardless of the temperature of the evaporator.

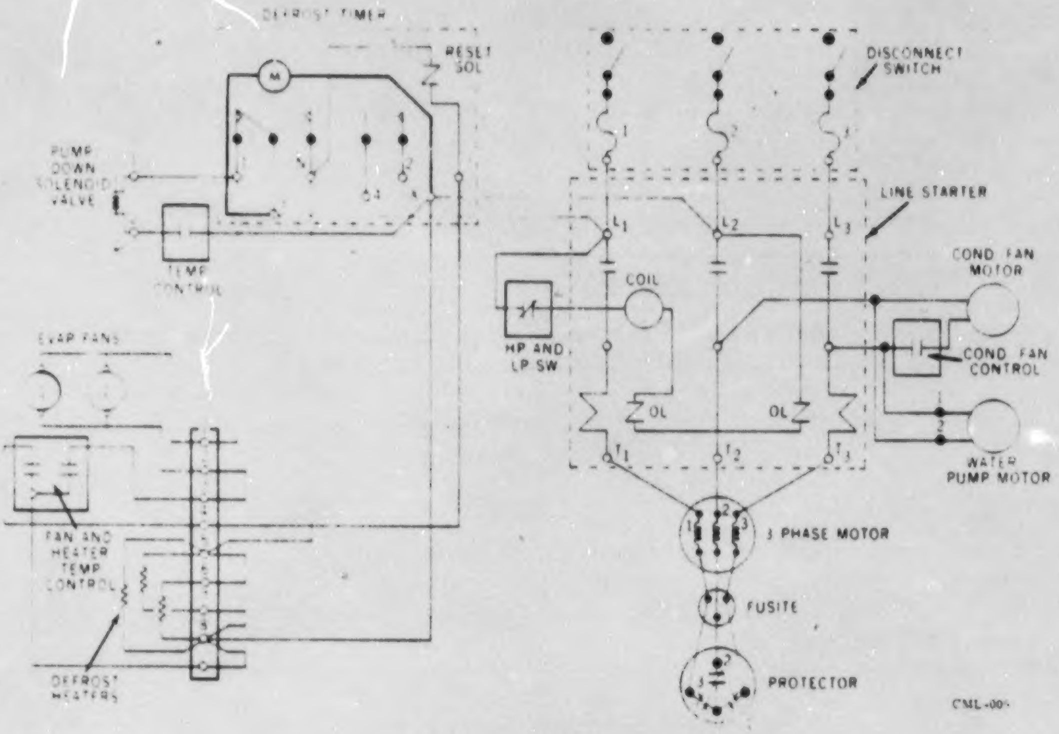

DEFROST TIMER
RESET SOL
M
PUMP DOWN SOLENOID VALVE
TEMP CONTROL
EVAP FANS
FAN AND HEATER TEMP CONTROL
DEFROST HEATERS
DISCONNECT SWITCH
LINE STARTER
L1
L2
L3
COIL
HP AND LP SW
OL
OL
T1
T2
T3
COND FAN MOTOR
COND FAN CONTROL
WATER PUMP MOTOR
3 PHASE MOTOR
FUSITE
PROTECTOR
CML-005

Figure 5. Walk-In Freezer Electrical System

Time initiated-temperature terminated. This timer can be used for all applications. They are usually set to defrost once each six to eight hours. Suppose the timer is set to defrost every six hours. At the end of six hours the timer will initiate the defrost cycle. If the box is under heavy usage and a lot of moist air has entered the box, there will be a thick sheet of ice on the evaporator. It may be necessary to apply electricity to the heaters for 12 to 15 minutes before all the ice is melted. If the box is under very light usage there will be very little ice formed on the evaporator. Applying heat for two to three minutes will be sufficient. This is an advantage. Enough heat is applied to complete the defrost but never overheat.

Time initiated-pressure terminated. This timer is very similar to the time initiated-temperature terminated defrost timer. The main difference is that this timer turns the defrost heaters off and puts the system back in normal operation when the suction pressure reaches a predetermined point. This is accomplished by a bellows that senses an increase in suction pressure and reverses the position of the contacts in the timer. This defrost timer must not be used with a hot gas defrost system.

3c

TROUBLE ANALYSIS OF COMMERCIAL UNITS. Determining the cause of a malfunction in a refrigeration system is usually more difficult than repairing it once the trouble is located.

It is important that a step-by-step procedure be utilized when troubleshooting a system. A remove and replace type procedure can result in a waste of time and may compound the trouble rather than correct it.

You, as a refrigeration specialist, should listen to the user's complaint. Sometimes this will give a clue to the possible trouble.

The mistake made by most refrigeration specialists is in forming an opinion without properly checking the equipment. The result is wasted man-hours and equipment.

The following is a trouble analysis chart which may be an aid to you in finding possible troubles.

TROUBLE ANALYSIS CHART

1. Complaint: Compressor fails to START

Symptoms	Probable Cause	Recommended Action
a. Electric circuit test shows no current on line side of motor starter	Power failure	Check for blown fuse or broken lead
	Disconnect switch open	Determine why switch was open. If everything is satisfactory, close switch
b. Electric circuit test shows current on line side but not on motor side of fuse	Fuse blown	Replace fuse, check load on motor
c. Full voltage at motor terminals but motor will not run	Burned-out motor	Replace motor
d. Inoperative motor starter	Burned-out holding coil or broken contacts	Replace
e. Compressor will not operate	Frozen compressor due to locked or damaged mechanism	Repair or replace compressor

f. System can be restored by resetting oil pressure safety switch, but will stop after 1 to 2 minutes of operation	Oil pressure safety switch has cut out	Check oil level, oil pressure, wiring and control
g. Starter will not energize	Overload contacts open	Reset overload contacts and determine cause of failure
2. Compressor loses oil		
a. Oil level too low	Insufficient oil charge	Add sufficient amount of proper compressor oil
b. Oil level gradually drops	Faulty system design causing oil to be trapped in the evaporator	Install oil separator
	Oil not returning from oil separator	Replace the oil separator
	Leak in the system	Repair the leak and add proper amount of oil and refrigerant
3. Complaint: Compressor is noisy		
a. Compressor cuts out on oil pressure safety switch	Lack of oil	Add oil
b. Compressor knocks	Internal parts of compressor broken	Overhaul compressor
c. Abnormally cold suction line. Compressor knocks	Liquid "flood back"	Check and adjust superheat Check for loose bulb on suction line Install heat exchanger

d.	High head pressure. Water valve chatters or hammers	Dirty water regulating valve--too high water pressure or intermittent water pressure	Clean water valve Install an air chamber ahead of the valve
e.	Abnormally cold suction line. Suction pressure high. Compressor knocks	Expansion valve stuck open	Repair or replace expansion valve
f.	Compressor jumps on base	Compressor loose on base	Tighten compressor holddown bolts

4. Complaint: Compressor "short cycles"

a.	Normal operation except too frequent stopping and starting	Intermittent contacts in electrical control circuit	Replace faulty control
		Low pressure control differential set too close	Reset differential in accordance with proper job conditions
b.	Normal operation except too frequent stopping and starting on low-pressure control switch	Low refrigerant charge	Repair the leak and recharge the system
c.	Suction pressure too low and moisture condensation at the strainer	Clogged strainer	Clean strainer

5. Complaint: Compressor runs continuously

a.	High temperature in conditioned area	Excessive load	Check the size of the load. Check for adequate insulation.
b.	Low temperature in conditioned area	Thermostat faulty or out of adjustment	Adjust or replace thermostat
c.	Bubbles in the sight glass	Lack of refrigerant	Repair leak and charge the system
		Restriction in the liquid line	Remove the restriction
		Excessive pressure drop in liquid line	Increase the head pressure or install a larger liquid line
		Liquid line picking up heat	Check for the source of heat from such things as steam lines, space heaters, steam tables, etc.

d.	Compressor noisy or operating at abnormally low discharge pressure or abnormally high suction pressure	Leaky valves in compressor	Overhaul compressor
6.	Complaint: Compressor runs continuously, conditioned space warm		
a.	Suction pressure low, head pressure low (for an operating unit)	Low refrigerant charge	Charge the unit
b.	Suction pressure above normal, head pressure below normal (for an operating system)	Compressor suction valves	Repair compressor
c.	Unit uses a capillary tube and from a visual inspection appears to be operating correctly	High head pressure caused by a dirty condenser	Clean condenser
7.	Complaint: Discharge pressure too high		
a.	Excessively warm water leaving condenser	Too little or too warm condenser water	Provide adequate cooling water, adjust water valve
		Load too large for the unit	Figure the total heat load and use a larger unit if necessary
b.	Excessively cool water leaving condenser	Dirty condenser	Clean condenser
c.	Exceptionally hot condenser	Air or noncondensable gases in system	Purge
		Overcharge of refrigerant	Remove excess refrigerant
		Dirty air-cooled condenser	Clean condenser

8.	Complaint: Discharge pressure too low		
a.	Excessively cold water leaving condenser	Too much condenser water	Adjust water-regulating valve
b.	Discharge pressure so low the unit will not operate satisfactorily	Air entering air-cooled condenser is too cold	Move condensing unit to controlled atmosphere
9.	Complaint: Suction pressure too high		
a.	Compressor runs continuously	Excessive load on evaporator	Check for excessive use of box, poor insulation, or defective door seal
b.	Abnormally cold suction line. Liquid flooding back to compressor	Overfeeding of expansion valve	Regulate superheat setting of expansion valve. Check to see that remote bulb is properly attached to suction line
		Expansion valve stuck open	Replace expansion valve
c.	Noisy compressor	Broken suction valves	Repair compressor
10.	Complaint: Suction pressure too low		
a.	Bubbles in sight glass	Lack of refrigerant	Repair leak and charge system
b.	Reduced flow of refrigerant through expansion	Clogged strainer in expansion valve	Clean strainer
c.	Conditioned space too cold	Thermostat faulty	Adjust or replace thermostat

WATER COOLERS. The purpose of the water cooler is to cool drinking water. It is sized according to the amount of water it will cool in one hour. Water coolers come in a variety of sizes and shapes. A typical water cooler is shown in figure 6. The cabinet is sheet metal with a steel frame and top. The condensing unit is located in the bottom half of the cabinet with the water cooling mechanism in the top half. The water cooling mechanism is usually insulated with corkboard, fiberglass, or plastic foam. One or more of the sheet metal side panels are removable for maintenance purposes.

Water coolers are used in office buildings, schools, mess halls, barracks, clubs, and other areas where people work or congregate.

There are two types of water coolers: self-contained and remote cooled.

Self-contained units are usually equipped with one bubbler and produce about five gallons of 45° water per hour. They usually use a hermetically sealed compressor with an air-cooled condenser. After normal installation and adjustment, these units will give years of trouble-free service. However, periodic cleaning and regular preventive maintenance should not be neglected.

Large self-contained units as shown in figure 7 may be equipped with two or more glass fillers and bubblers. These units are used in hospitals, mess halls, and cafeterias. They may have a capacity of as much as 25 gallons of cooled water per hour.

Remote units have the water cooling mechanisms in one place or housing and the condensing unit in another. These water coolers are normally installed as a permanent fixture in areas where space is plentiful.

Water coolers are classified as instantaneous or storage. From an outward appearance these two units look alike. The difference is in the method of cooling the water. Instantaneous water coolers hold only a small amount of water and depend on a large evaporator surface and rapid refrigeration to cool the water as it is needed. This type water cooler chills water only as it is being drawn from the cooler. The refrigeration equipment must be large enough to cool the water as it is being drawn from the cooler. These units are more expensive, due to the larger refrigeration equipment, than the storage type but they work more satisfactorily in applications where there is a constant demand for long periods of time.

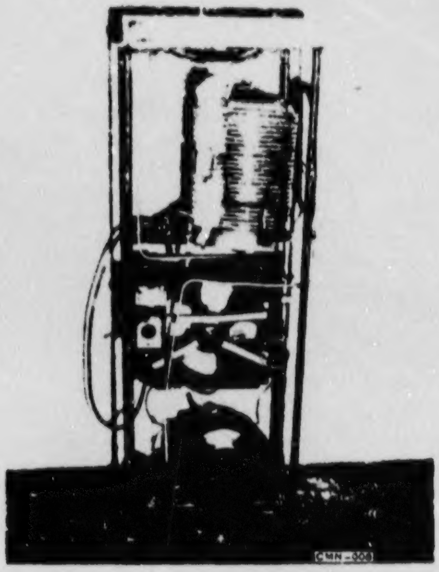


Figure 6. Water Cooler

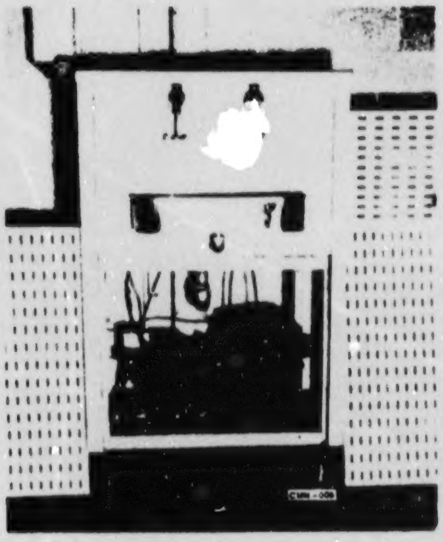


Figure 7. Large Self-Contained Water Cooler

Storage type water coolers chill and hold in reserve a small amount of cold water. This cold water may be used even when the condensing unit is not operating. Small storage type coolers have a capacity of about two gallons. When this cold water has been used, the unit must be allowed to operate for a short time before additional water is available. As the cold water storage area is increased, the amount of cold water available at any given time increases but the running time to cool this water also increases.

Major Components. All water coolers use approximately the same major components. These components may be arranged differently, be a different size or shape, but if you know the components on one unit, you can figure them out on any system. Following are typical units in a water cooler system:

- Condensing unit. Self-contained units usually use a small low-starting torque compressor and an air-cooled condenser, as in figure 7. The condensing unit is usually mounted on the bottom part of the water cooler.

- Evaporator. The evaporator is usually a coil of copper tubing on either the inside or outside of the water tank.

- Refrigerant Controls. Small water coolers use a capillary tube refrigerant control. The capillary tube is very economical and allows the use of a low-starting torque compressor. Larger type water coolers use an automatic expansion valve. The automatic expansion valve maintains a set pressure in the evaporator. This eliminates the possibility of overloading the compressor when an excessive amount of warm water enters the water tank.

- Bubbler. The bubbler is the pressure-reducing valve that controls the flow of water to the user. As a refrigeration and air-conditioning specialist, it will be your job to adjust the bubbler. The water flow should be high enough for ease of drinking but not high enough to splash on the floor or surrounding area.

- Thermostat. The motor is controlled by a thermostat that senses the temperature of water. The thermostat should be adjusted to maintain 50° water for office personnel and 55° water for people performing manual labor.

- Freezestat. Some units are equipped with a safety freezestat. If the thermostat fails, the freezestat will stop the unit when the water temperature reaches 33°F. This keeps the water from freezing in the tank and damaging the equipment. Exceptionally cold water at the bubbler indicates that the thermostat is faulty and that the unit is being cycled by the freezestat.

- Heat Exchanger. Most bubbler-type water coolers are equipped with water-to-water heat exchangers. These heat exchangers utilize the cooling effect of the waste water from the bubbler to precool the warm water entering the cooler, making it more efficient.

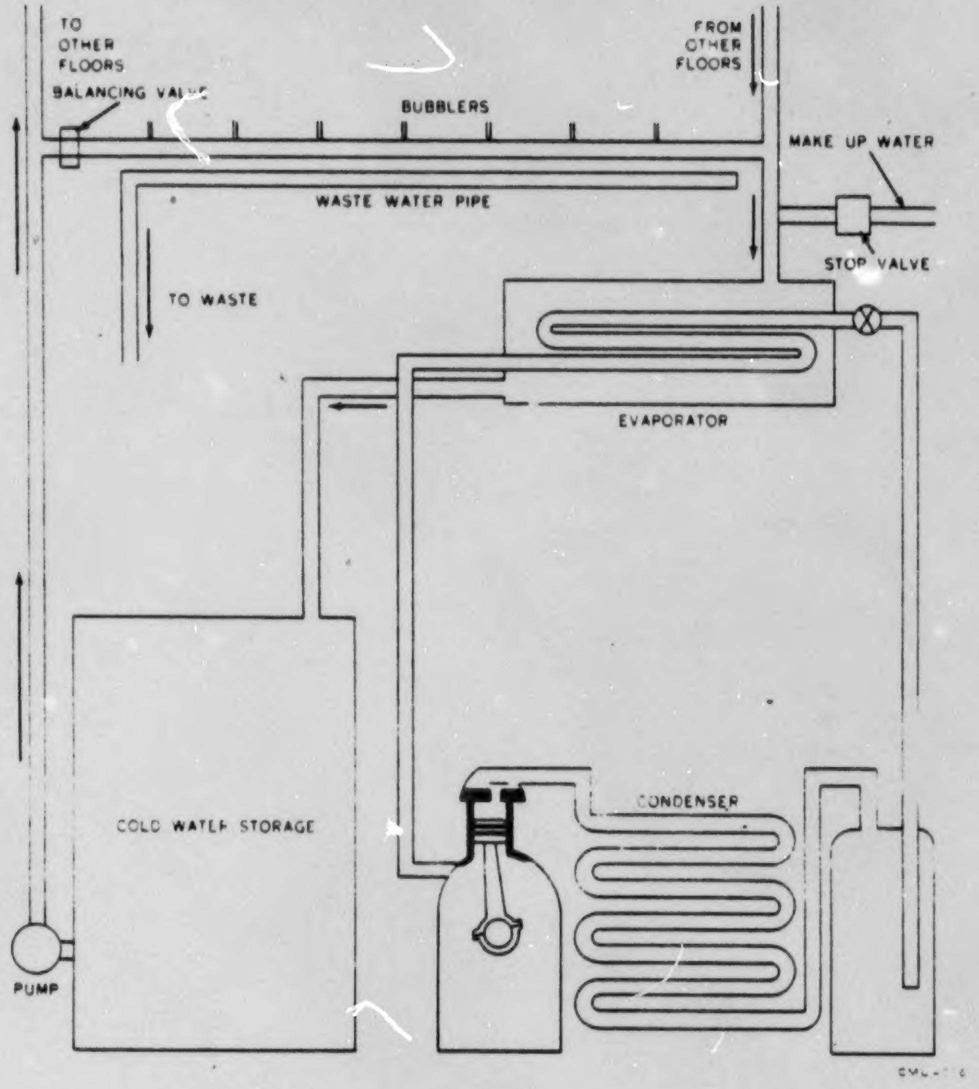

TO OTHER FLOORS
BALANCING VALVE
BUBBLERS
FROM OTHER FLOORS
MAKE UP WATER
WASTE WATER PIPE
STOP VALVE
TO WASTE
EVAPORATOR
CONDENSER
COLD WATER STORAGE
PUMP

Figure 8. Drinking Water System

Drinking Water System. Figure 8 illustrates a typical drinking water system used in an office building. The water is cooled in the evaporator and goes to an insulated cold water storage tank. On some applications you will find the evaporator installed in the cold water storage tank. These cold water storage tanks vary from 10 to 500 gallons or more according to the size of the building and the number of people accommodated. A centrifugal pump continually circulates the cold water through the building. This guarantees a supply of cold water at each bubbler all the time. The water that is not used returns to the evaporator to be recooled and start another cycle. Makeup water is added automatically as needed.

This type of water system is very satisfactory for use in office buildings, hospitals, schools, and any other areas where a large number of people must be furnished cold drinking water. The temperature of the water should be about 50 degrees at the bubbler. The temperature of the water leaving the evaporator may have to be as low as 40 degrees to guarantee 50 degree water at the bubbler.

REACH-IN BOXES. This is one of the most widely used commercial refrigeration units. It is used as a cold storage area and display fixture in snackbars, commissaries, hospitals, and mess halls. It is used in any application where there is a need for greater capacity than can be afforded by a domestic refrigerator.

Reach-ins that are used in commissaries to display food products for sale are equipped with glass windows. To reduce the heat loss, these windows have two or three panes of glass. Those used in dining halls and kitchens have solid doors because they are exposed to direct radiated heat from cooking equipment.

Reach-ins (figure 9)are made in a wide variety of capacities from 16 cubic feet to 100 cubic feet or more. They are available in both self-contained units and with remote condensing units.

The exterior of the box may be constructed of aluminum or steel. The interiors are usually of enameled steel, aluminum or porcelain. The insulation is usually three inches of fiberglass or its equivalent.

Reach-ins usually have a finned forced convection evaporator and maintain an above freezing temperature. However, one manufacturer is producing a reach-in that maintains 0° for the display and sale of frozen foods.

Due to the various locations, usage and product loads imposed on reach-ins, it is impossible to accurately determine the correct condensing unit size without knowing these factors. Most self-contained units use about $\frac{1}{4}$ horsepower for each 15 cubic feet of refrigerated space.

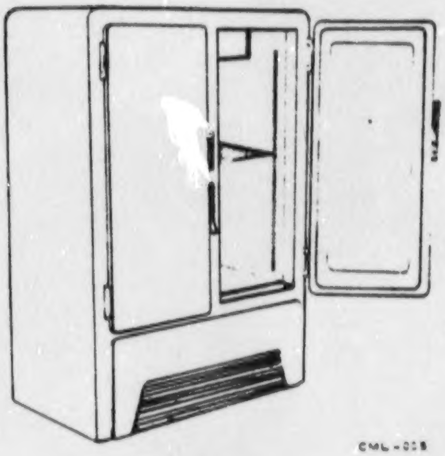


Figure 9. Reach-In Box

The requirements for cleaning, door adjustment, and location of reach-ins are the same as for domestic boxes. There must be an ample supply of ventilating air provided to remove the heat.

DISPLAY CASES. A variety of display cases are being manufactured for the display of meats, vegetables, ice cream, dairy products, candy, and frozen foods. Each type of unit has its own special design and arrangement.

Display cases are classified as to open or closed type and whether it is single- or double-duty.

Closed Type. The closed type (see figure 10) utilizes a large glass area to display the food products. This area is covered with two or more panes of glass. This presents a problem when transporting the units at high altitudes. The area between the panes is filled with very dry air to reduce sweating. At high altitudes the dry air between the panes has a higher pressure than the atmospheric pressure. This will cause the dry air to expand and crack the panes.

Open Type. The open-type display case is utilized for easy self-service of meat, vegetables, frozen foods, and dairy products. They may be designed for service from one side only, as illustrated in figure 11, or they may be the island type without the top for service from all four sides. The open-type display case may be visualized as a tank or bin full of cold air. The cold air is heavier than the surrounding air so it stays in the bin in much the same way as the water stays in an open tank.

Single-Duty Units. In single-duty units, only the top part of the case is refrigerated. The bottom part is left open. This is the most economical unit to buy and operate.

Double-Duty Units. Both the top and bottom sections of these units are refrigerated. The top section is used as display space and the bottom area is used as storage. These units cost a little more but they provide convenient refrigerated storage without taking up additional floor space.

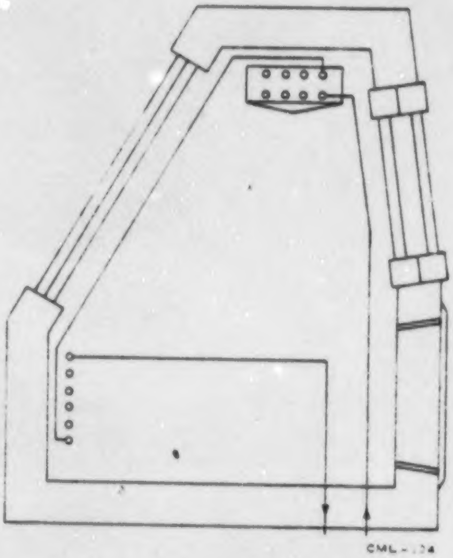


Figure 10. Closed Display Case

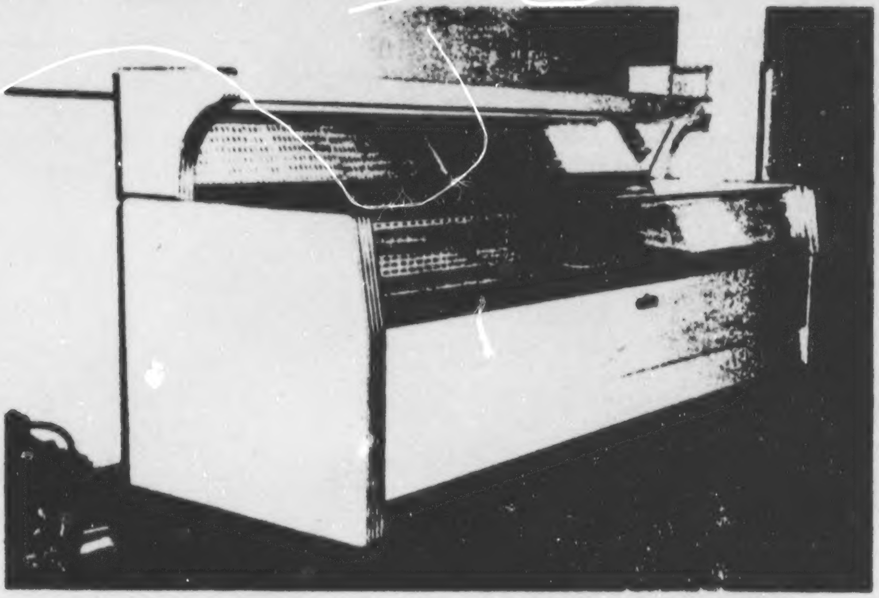


Figure 11. Open Type

Perfect food preservation conditions cannot be maintained in a display case if the condensing unit fails. The food should be transferred from the display case to a walk-in if the store is to be closed over the weekend.

Troubleshooting Display Cases. Listed below are some of the problems that you can expect to encounter with open-type display cases.

Product Temperature. Display cases are not designed to lower the product temperature. The product must be at or below the correct storage temperature before being placed in the display case. A complaint that the condensing unit on a frozen meat case runs all the time can often mean that the box has just been filled with a product that is at or near its thawing temperature.

Keeping Product within Load Lines. This is a very prevalent abuse of self-service display cases. The person filling the base of the display case pays very little attention to the fill lines and piles the box as full as possible. There is very little that the refrigeration and air-conditioning specialist can do about this condition. All you can do is to instruct the user on the correct filling procedures and hope for the best.

Drafts. If you get a complaint that includes high box temperature, excessive coil frosting, and long operating time, check the air velocity around the unit. Air movement in excess of 20 fpm is excessive. It may be necessary to either relocate the display case, change the position of an outlet grille, or build a partition to divert the air away from the case.

Radiant Heat. The radiant heat from lights, heaters, or windows will affect the product temperature as well as the operating time of the unit. The only remedy is the elimination of the cause of the radiant heat.

High Store Humidity. A store humidity in excess of 55 percent cannot be tolerated. You must maintain a relative humidity of less than 55 percent or else use closed-type display cases.

Improper Airflow. The air must be free to flow from the evaporator around the product and return to the evaporator. Any restriction of the airflow will reduce the efficiency of the unit and increase the temperature of the product.

Low Head Pressure. This condition is usually caused by operating the condensing unit in a low ambient temperature area. Several manufacturers produce controls designed to maintain the head pressure. These controls usually operate on the principle of flooding the condenser with liquid refrigerant to reduce the effective condenser area. These systems are both complex and costly. It is much better to operate the condensing unit in an equipment room where the temperature can be maintained above 70°F.

Oil Logging. Oil logging reduces the efficiency of the evaporator. If enough oil stays in the evaporator, the compressor may be damaged. Oil logging is more prevalent in low-temperature R-22 systems than in other types. However, it can happen in any system with any type of refrigerant. Units equipped with an automatic defrost system are seldom bothered with oil logging problems. The oil in the evaporator is heated to 37° to 40°F during the defrost cycle. This warm oil is easily pulled back to the compressor at the beginning of the next freezing cycle.

Poor Draining. The condensate water drains out by the force of gravity only. Drains that are too small or one that does not have enough pitch will stop up. This stoppage is usually caused by lint, dirt, and other types of foreign matter. If a drain continues to give trouble, replace it with a larger one or give it a little more pitch.

Improper Defrost. Open-type low-temperature display cases will have three or four defrost cycles per day. Each defrost cycle must be complete. If any frost is left on the evaporator at the end of the defrost cycle, it will continue to build up until half or more of the evaporator is frozen solid.

If you are having defrost problems, perform the following items in succession:

Increase the length of the defrost cycle (time initiated, time-terminated defrost system).

Increase the number of defrost cycles per 24 hours.

Check the function of the termination thermostat (time-initiated, temperature-terminated systems).

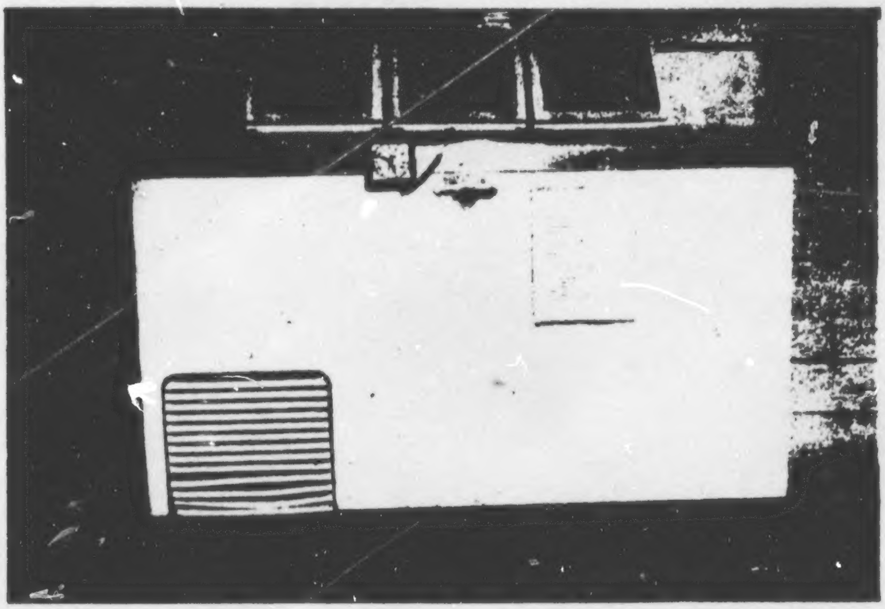


Figure 12. Ice Cream Cabinet

ICE CREAM CABINET. One of the most widely used refrigerated fixtures is the ice cream cabinet. Made for holding low temperatures, this fixture is used to store ice cream, sherbets, frozen foods, and any other product requiring a low temperature.

Ice cream has a critical temperature. If the temperature is too high, the ice cream will melt and if the temperature is too low, the ice cream will crystallize and become unpalatable. Bulk ice cream has a serving temperature of about 10° to 15°F. Ice cream at 5°F or less is too hard to be dipped easily. Most packaged ice creams can be stored at 0° to 6°F very satisfactorily.

Ice cream cabinets require a relatively large condensing unit and ample evaporator surface. Normally, plate-type evaporators are used, see figure 12, but at the present time forced convection evaporators are becoming very popular. Some type of automatic defrost system must be used with this type of evaporator. The electrical defrost system is the most popular but some manufacturers use the hot gas system.

FROZEN FOOD STORAGE BOXES. These boxes are often referred to as home freezers because they were first developed for the storage of frozen foods in the home. These boxes may be either the chest or upright type. The chest type operates more economically and the temperature fluctuations are not as great as with the upright type. The upright-type box was developed so that a large box would not take up too much floor space. The greatest disadvantage of the upright box is that each time the door is opened, the cold air spills out and is replaced with warm air. This not only causes the unit to operate longer but also causes a large temperature fluctuation within the box.

The insulation, evaporator type and size, and defrost problems are the same as for ice cream cabinets.

INSTALLATION PROCEDURES FOR COMMERCIAL REFRIGERATION SYSTEMS. When installing commercial refrigeration systems, the first problem to be solved is the location of the cabinet. It is only natural that you should place the cabinet in the most convenient location for the customer. However, you should also consider such factors as: the location of a drain for the condensate water, electrical supply for lights and defrost, if necessary, and the possible location of the refrigerant lines. After determining the location of the cabinet, the next problem is to determine the location of the condensing unit. The condensing unit should be placed as close to the cabinet as possible to reduce the length of the suction line. If possible, place the condensing unit in an equipment room where the temperature can be maintained between 70° and 100°F. If the condensing unit is placed outdoors, the head pressure may (in cold weather) drop down so low that the unit will not operate. If the condensing unit is located above the evaporator, it may be necessary to use a dual suction riser to insure oil return when operating at partial loads.

Refrigeration tubing comes in 50-foot rolls. This tubing is sealed and has been dehydrated and cleaned for use in refrigeration systems. You should keep this tubing sealed as much as possible. It has always been considered that the main purpose of sealing the tubing was to keep out air and moisture. That is important, of course, but it is also important to keep foreign matter out of the system. A vacuum pump and a drier will eliminate small amounts of air and moisture, but if you get a foreign matter in the system, you have trouble.

The liquid line does not present any problem as to slants and position. However, the suction line should always slant toward the compressor to aid oil return. For obvious reasons, the tubing should never be run near sources of heat such as hot water or steam line, heaters, etc. The tubing must be supported enough to keep it from sagging. It also must be protected from accidental damage. Small tubing (1/4 to 3/8 inch) can be bent relatively easily by hand but large tubing requires a tube bender. Due to their lower cost, soldered connections should be used instead of flared connections wherever possible. It is good practice to use flared connections at the receiver outlet, drier, strainer, expansion valve, and compressor service valves.

The installation of commercial refrigeration equipment should follow this sequence:

1. Set the cabinet in its proper place.
2. Locate and install the condensing unit.
3. Run and install the liquid and suction lines.
4. Properly position the compressor service valves and the king valve.
5. Pressurize and leak test the system.
6. Evacuate the system.
7. Fabricate or install a heat exchanger on the system if needed.
8. Insulate the suction line.
9. Connect all electrical wiring.

WHILE THE UNIT IS BEING INSTALLED, ASK YOURSELF THESE QUESTIONS:

1. Does this job represent [illegible] professional appearance?
2. Is there evidence of poor and shabby workmanship?
3. Is there a possibility of the refrigerant or electrical lines vibrating, rubbing, or chafing?
4. Are the service valves readily accessible?
5. Can you see the sight glass easily?
6. Can the drier be replaced easily?
7. Can the condenser be cleaned easily?
8. Is the airflow around the compressor motor, overload, or relay restricted in any way?
9. How much work will be required to check the starting capacitor, overload, and starting relay?
10. What will another refrigeration and air-conditioning specialist think of this job?

Perform the following preoperational checks:

1. Check the oil level. Normally, the new equipment contains the correct amount of oil. However, it is always better to check and make sure. Use the manufacturer's data to determine the correct oil level. If the manufacturer's data is not available, adjust the oil level to the center of the crankcase sight glass.

2. Remove the shipping bolts.

3. Check the belt tension. A "V" belt should operate as loose as possible, yet it must be tight enough to eliminate flopping and slippage. If the belt is too tight, it will overload the motor.

4. Check motor alignment. If the motor and compressor are out of alignment, it will cause excessive belt wear and power consumption.

5. Check all fans for freedom of rotation and oil the motor, if necessary.

6. Check and make sure the refrigerant and electrical lines are not rubbing.

7. Check the proper position of the compressor service valves and king valves.

8. Make initial adjustments on the motor controls.

9. Break the vacuum and charge the unit.

Perform the following operational checks:

1. Complete the charging of the system.

2. Make final adjustments of the motor controls.

3. Check for any vibrations or unusual noises while the unit is running.

4. Observe all pressures and temperatures.

5. After 30 minutes operation, check oil level in compressor.

6. CAUTION: Do not adjust, clean, or lubricate parts that are in motion. These procedures do not have to be accomplished in this exact order. While the vacuum pump is operating, you can insulate the suction line. Also, the electrical wiring can be done at anytime.

Adjust Motor Controls. At the present time, there are several manufacturers making motor controls. Each of these controls uses the same basic principles of operation. If you understand the principles of operation and application of controls, you can adjust any control with very little difficulty.

Before adjusting any control, the first thing you should do is determine the average box temperature. The next thing to determine is the allowable range that is the difference between the cutout and the cut-in. The range should be as small as possible without causing the condensing unit to short cycle. Normally, commercial units use a range of 10°.

The next thing to determine is the TD of the evaporator. When we speak of TD of an evaporator, we are talking about the temperature difference between the boiling refrigerant in the evaporator and the temperature of the air leaving the evaporator. After determining the average box temperature, range and evaporator TD, you can now make out a condition sheet.

Assume the following conditions:

Average box temperature 40° and differential 10°F

Evaporator TD 10°

Step 1. Make a condition chart as illustrated below.

	Box Temp	Evap Temp	Suction Pressure
Cut-in			
Cutout			
Differential			

Step 2. Determine the cut-in and cutout. If the average box temperature is 40° with a range of 10°, the cut-in will be 5° above 40° and the cutout will be 5° below. Therefore, the cut-in is 45° and the cutout is 35°. Place these figures in the chart.

Step 3. Subtract the cutout from the cut-in. This figure (10°) is the temperature differential.

Step 4. Fill in the evaporator temperature block. With the compressor off and the evaporator fan running, at the cut-in, the evaporator and box temperature will be the same. Place the figure 45° in its proper place.

Step 5. At cutout, the evaporator temperature will be 10° less than the box temperature. We are using a 10° TD evaporator. Place the figure 25° in its proper box.

Step 6. Use your temperature pressure relationship chart and look up the suction pressure for 45° and 25°. In this case, it is 41.6 and 24.6. Place these figures in their proper places.

ICEMAKERS. Ice makers are self-contained units that efficiently produce clean, clear ice automatically. These machines consist of two sections: the icemaking section and the insulated bin section. Production is controlled automatically by the use of a bin thermostat. Icemakers produce ice in a variety of sizes and shapes. These pieces of ice may be classified as ice flakes, ice cubes, ice pellets, and ice pieces. Often the term ice cube, is applied to any piece of ice, regardless of ice size and shape.

Cube-Type Icemaker. Ice cube makers are automatic self-contained units that provide a supply of clear ice cubes. These machines consist of two sections: The ice-making sections and the insulated bin section. The unit cycles continuously to keep the insulated bin full at all times. Production is controlled by the use of microrelays or thermostats in the bin.

The icemaking section consists of four major systems.

A hermetically-sealed refrigerant system that freezes the ice.

An automatic water system.

A harvesting system (hot water or hot gas) melts the ice from the surface.

Necessary controls to start and stop each cycle.

Since ice is a food product, it is highly important that the icemaking equipment be kept clean. The water tank should be drained and flushed and the entire system cleaned periodically.

In areas where the water contains a high concentration of solids, the ice may become cloudy and develop a bad taste. This condition is best eliminated by the use of water softeners and water-treating equipment. If this equipment is not available, a periodic blowdown (flushing the water pan) will help.

Flake Icemaker. This type of ice maker produces small flakes of clear ice, utilizing a continuous noncycling process. There are three types of flake ice makers: The Stationary and Rotary Drum, and the Auger type. Flake machines will produce more ice because of the noncycling process.

Rotating Drum Icemaker. The icemaking evaporator drum consists of a stainless steel external cylinder shrunk on an internal steel shell. The internal sheet contains continuous tapering, spiral passage for the refrigerant circuit. The exterior of the stainless steel cylinder is the ice-making surface. The evaporator drum is mounted in a horizontal position and is driven by a gear motor.

The refrigerant passes through the hub of the drum and goes through an automatic expansion valve into the evaporator. Water is then sprayed on the outside of the evaporator (Drum). The refrigerant freezes water into thin sheets of ice. The drum rotates and a cutter assembly scrapes the ice from the drum and directs it into the storage bin.

The rotary hub seal (where the refrigerant enters the drum) may develop a leak and have to be replaced.

Stationary Drum Ice-Flake Machine. The evaporator is stationary and is installed in a vertical position. Water is sprayed on the evaporator and the refrigerant freezes it into thin sheets of ice. The cutter assembly rotates around the drum, scrapes off the ice, and directs it into the storage bin. The main advantage of this system is the elimination of the rotary hub seal.

Auger-Type Ice-Flake Machine. This is a very simple type of ice maker. The ice-making mechanism consist of two cylinders, one inside the other (see figure 13). The space between the two cylinders is the evaporator. The inside is the freezing section where the ice is formed. The cylinder is approximately the size of a 1-lb coffee can installed in a upright position.

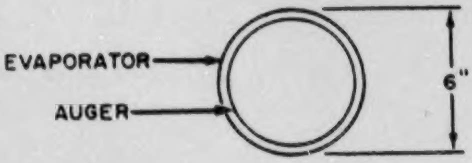


Figure 13. Icemaking Section (Top View)

Water drains by gravity from the sump tank into the inner cylinder. The water level in the inner cylinder is determined by the level and position of the sump tank. The evaporator freezes a thin sheet of ice on the inner cyclinder surface (wall). The auger is turned very slowly by a motor and gearbox. As the auger turns it scrapes the ice off the inner cylinder wall (evaporator surface) and pushes the ice up to the top and out into the storage bin thru an ice chute. (See figure 14).

On some types of auger machines, the water is pumped up to the top and allowed to flow down the sides of the inner cylinder. The cold inner surface (evaporator) freezes part of the water flowing down the inside of the cylinder into a thin sheet of ice. The action of the auger in this machine is the same as the flooded evaporator's operation.

Ice Cube Makers. Ice cube machines make all different sizes and shapes of ice cubes. They are sometimes referred to by the shape of the ice they make. The refrigeration system is the same as any other system. All ice cube makers have a water system and a harvest cycle.

The harvest cycle is when the ice is being melted from the molds. There are two methods used, hot water and hot gas.

The most common maintenance problems are in the water system; water pump, makeup water leaking into sump tank, scale and dirt.

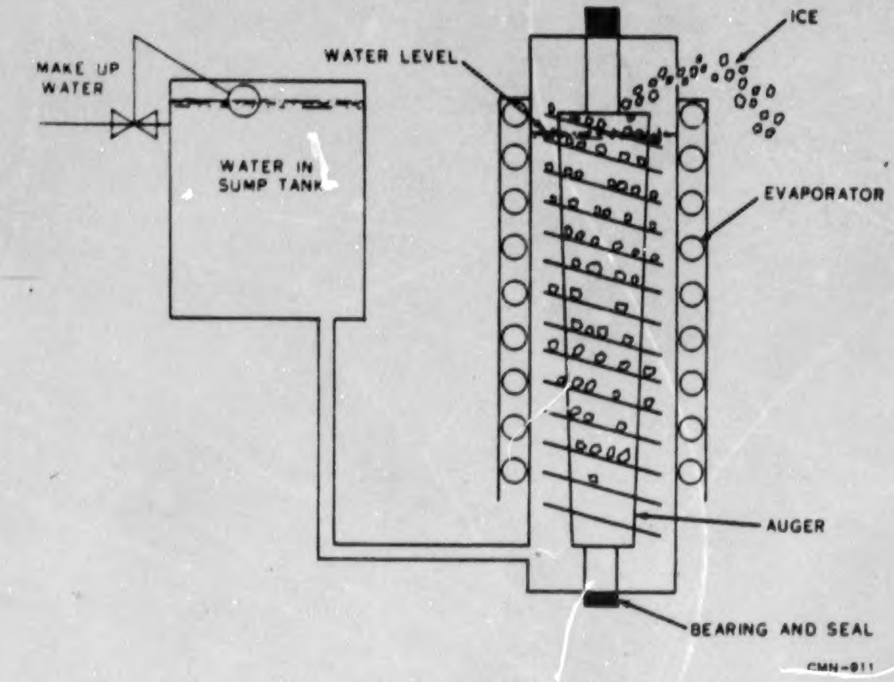


Figure 14. Auger Ice Flake Machine

Operation of an Ice Cube Maker (Fig. 15). Water enters the machine through the makeup water line. When the water level builds up in the sump tank a float valve shuts the water off. Water flows from the sump tank to the pump, water flow switch, into the inner tube of the evaporator and back to the sump tank. The water continues to circulate through this path as the water freezes to the walls of the inner tube. Water continues to flow through the center of the ice. As the opening through the center of the ice gets smaller the amount of water flow will decrease and the water pressure will increase. The increase in water pressure causes the bypass regulator to open, bypassing water into the pump suction. The decrease in waterflow is sensed by the waterflow switch and the increase in water pressure is sensed by the water pressure switch. Either of these switches will complete a circuit to the hot gas solenoid valve causing the valve to open, establishing the harvest cycle. The discharge gas now passes through the hot gas bypass line into the evaporator coil causing the ice to melt from the coil.

The hot gas increases the suction pressure causing the two-speed motor control to energize the high-speed winding in the water pump motor. This increases the pump output. The increased water pressure forces the ice out of the evaporator. As the ice leaves the tube the water pressure decreases and the waterflow increases causing the water pressure switch and waterflow switch to open their contacts. When the switches open the hot gas solenoid valve closes ending the harvest cycle. The suction pressure will now decrease causing the two-speed motor control to deenergize the high-speed and energize the low-speed on the water pump motor.

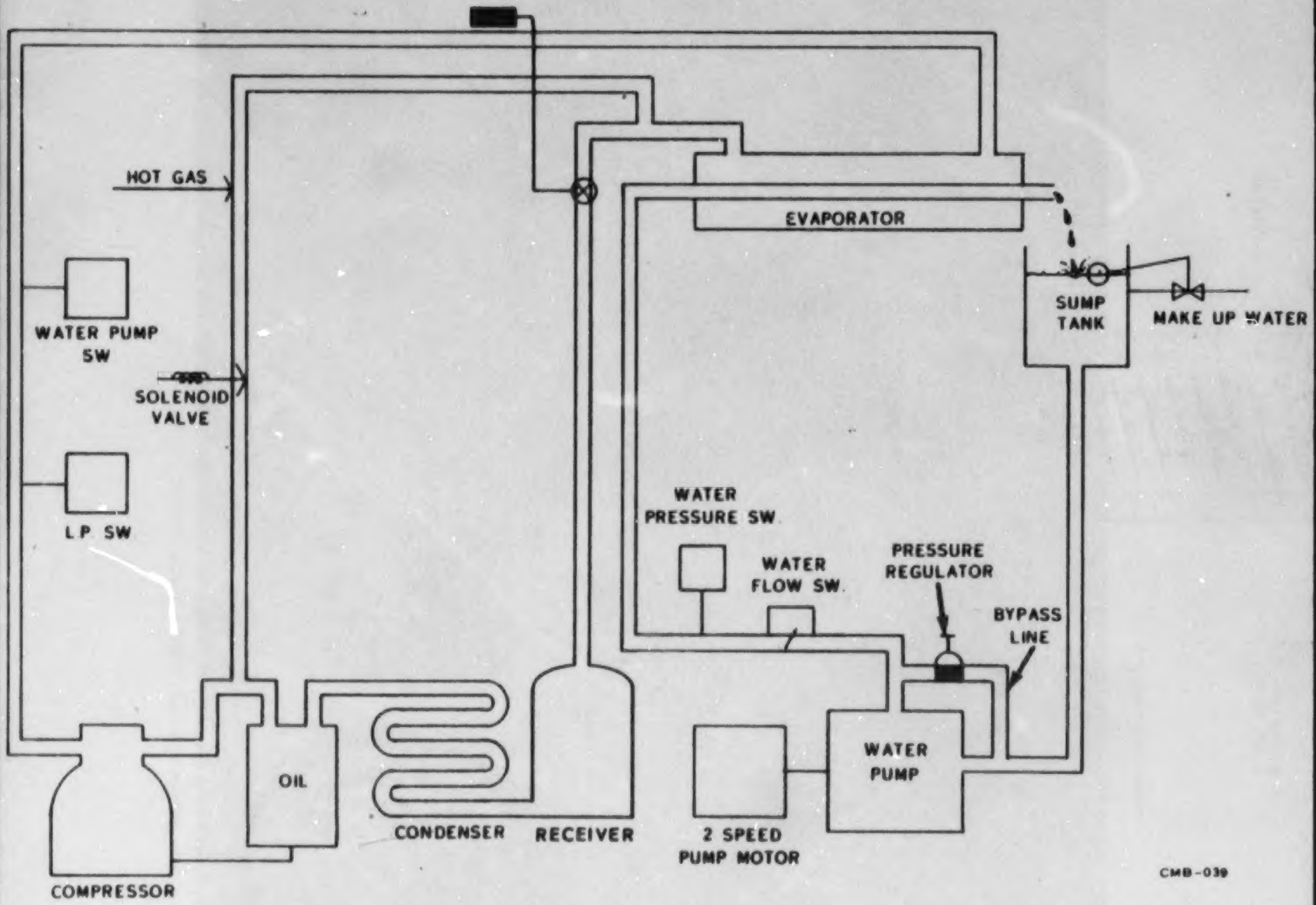

HOT GAS
WATER PUMP SW
SOLENOID VALVE
L.P. SW
EVAPORATOR
SUMP TANK
MAKE UP WATER
WATER PRESSURE SW.
WATER FLOW SW.
PRESSURE REGULATOR
BYPASS LINE
OIL
CONDENSER
RECEIVER
2 SPEED PUMP MOTOR
WATER PUMP
COMPRESSOR
CMB-039

Figure 15. Ice Cube Machine

Maintenance. Ice is a food product; therefore, it is highly important that the ice-making equipment be kept clean. Do not use strong (hydrochloric or sulphuric) acid to clean the ice making area. There are several commercial ice maker cleaners on the market. Most of these cleaners contain citric or acetic acid. It is possible to mix your own acid, but it is much better to procure a prepared mixture and follow the directions on the package. This will eliminate the possibility of contaminating the ice with acid.

SUMMARY

The commercial refrigeration field is so large that it is impossible to cover the exact service and maintenance procedures for each model and type of equipment. However, if you will follow the procedures covered here and apply a little ingenuity, you will have very little trouble servicing any type or model of refrigeration equipment. When working on hermetic systems such as water coolers, you will have to use the special tools and equipment covered when you were working with domestic boxes.

The service of refrigeration equipment can be divided into major parts: troubleshooting and repair. Of these major parts, troubleshooting is usually the most difficult, time-consuming, and exacting.

Occasionally, the cause of a trouble can be determined immediately; however, it is still a good policy to check and test each component in the system before making a final judgment. Often you will find that an obvious malfunction is in reality a symptom and not the trouble. If a compressor cuts out on the thermal overload, do not change the overload until you are very sure the trouble is not somewhere else. In this case, the trouble will probably be in the compressor and not the overload.

QUESTIONS

1. Name the three major areas of refrigeration.
2. Explain the scope of the:
   a. Domestic area
   b. Commercial area
   c. Industrial area
3. Name the two types of walk-in boxes.
4. List eight characteristics of good insulation materials.
5. List three common insulation materials.
6. Name the four sources of heat in a walk-in box.
7. Why must the motor protection on a three-phase motor be located in the control circuit instead of the power circuit.
8. Explain the principle of operation of the water defrost system.

9. Explain the principles of operation of the hot gas defrost system.

10. Explain the principles of operation of the electric defrost system.

11. Name the three types of defrost timers.

12. Which one of these three timers is not used with the hot gas defrost system?

13. Name three locations where water coolers are normally located.

14. Name two types of water coolers.

15. Explain the location and advantage of remote water coolers.

16. Explain the difference between instantaneous and storage water coolers.

17. Give one advantage and one disadvantage of:

    a. Instantaneous water coolers

    b. Storage water coolers

18. List and explain the types and functions of the major components of water coolers.

19. What is the recommended drinking water temperature for office workers?

20. What is the recommended drinking water temperature for outside workers?

21. Explain the reason for the balancing valve in an office drinking water system.

22. Explain one advantage and one disadvantage of open- and closed-type display cases.

23. Explain why closed-type display cases must be shipped by surface carrier or low-altitude aircraft only.

24. Explain the difference between single-duty and double-duty display cases.

25. What is the most widely used commercial refrigeration unit?

26. How many hp Condensing Unit should an 18-cu ft reach-in use for a temperature of 38°.

27. At what temperature should bulk ice cream be stored?

28. At what temperature should packaged ice cream be stored?

29. List one advantage and one disadvantage of upright frozen food boxes.

30. List three things to be considered when installing commercial refrigeration units.

31. Why should the condensing unit be placed in an equipment room instead of outdoors?

32. What is the purpose of a dual suction riser?

33. What is the main purpose of keeping refrigeration tubing sealed?

34. List the installation procedures for commercial units.

35. Name the two types of motor controls used in commercial refrigeration.

36. List the types of ice machines.

37. Name the sections of an ice cube machine.

38. Name the methods of harvesting used on ice machines.

39. What is used to clean the ice making section of an ice machine?

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WORKBOOKS 3ABR54530-V-2-P1 thru P7

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

COMMERCIAL UNITS

January 1975

SHEPPARD AIR FORCE BASE

11-7

Designed For ATC Course Use

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REFRIGERATION AND AIR-CONDITIONING SPECIALIST

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This supersedes SG 3ABR54530-V-2 and WB 3ABR54530-V-2-P1 thru P7, 15 October 1973 Copies of superseded publication may be used until the supply is exhausted.

Dept of Civil Engineering Tng
Sheppard AFB, Texas

WB 3ABR54530-V-2-P1
21 January 1975

MAINTENANCE AND TROUBLESHOOTING WALK-IN BOXES

OBJECTIVE

To learn to perform maintenance on walk-in refrigerators.

INSTRUCTIONS

Familiarize yourself with the walk-in refrigerator you are assigned to by filling in the blank spaces below, then complete the necessary maintenance on the refrigerator.

FAMILIARIZATION

1. Type and purpose of refrigerator
   a. Type ______________________________
   b. Purpose ______________________________
2. Type and manufacturer of compressor
   a. Type ______________________________
   b. Manufacturer ______________________________
3. Type of refrigerant ______________________________
4. Motor operates on ______________ volts ______________ phase.
5. Type of condenser ______________________________
6. Type of evaporator ______________________________
7. Type of metering device ______________________________

Procedure

Accomplish all preoperational checks listed on the next page prior to operation of the trainer (Walk-in) and observe the listed procedures closely during all operations.

PREOPERATIONAL CHECK

1. Electrical wiring for loose or broken wires
2. Conduit for secure mounting and possible rubbing
3. Compressor discharge, suction valves, and king valve for proper positioning
4. High pressure cutoff switch for proper setting

5. Motor control for proper setting
6. All fans for freedom of rotation
7. Check for obstruction (rags, tools, etc).
8. Check power supply for proper voltage and phase.
9. Check wiring connections at line starter, disconnect, etc

   NOTE: When applicable, perform steps 10 and 11.

10. Condenser water drain valve in closed position
11. Condenser water supply valve in condenser sump
12. Check condenser for cleanliness (clean as required).
13. Check evaporator coils for bent fins, dirt, and evidence of rubbing.
14. Check the evaporator supports, casing, and drain pan for dirt or rust. (Clean if necessary).

OPERATIONAL SAFETY CHECK

1. Remove all rings, watches, or jewelry

   NOTE: Perform step 2 when applicable

2. Set defrost timer out of defrost position
3. Set main power switch to on position
4. Check oil level (sight glass) after unit starts and again after 30 minutes of operation
5. Install manifold gage assembly.
6. Check refrigerant charge. (Charge if necessary)
7. Observe the operation of the expansion valve
8. Is the evaporator completely active? ____________________
9. Observe mechanical equipment for normal operation.
10. Record the pressures: High side ____________ Low side ____________
11. Investigate any unusual noises or vibrations. (Make repairs as necessary)

12. Safety: Do not adjust, clean, or lubricate parts which are in motion
13. Start at the receiver and trace the flow of refrigerant through the system
14. Check the condition of the door seal. (repair or replace if necessary)

POSTOPERATIONAL CHECK (shutdown)

NOTE: Perform step 1 and 2 when applicable

1. Rotate defrost timer to the defrost position
2. Wait until the unit pumps down and shuts off on low pressure control
3. Set main power disconnect switch to off position
4. Remove manifold gage assembly
5. Have the instructor check your work

Checked by ______________________
Instructor

WALK-IN FREEZER ELECTRICAL SYSTEM

OBJECTIVE:

To be able to troubleshoot a walk-in refrigerator using an electrical diagram.

1. Using the electrical diagram (Figure 1), complete the following:

2. What is the purpose of the fusite ______________________________

____

3. What is the purpose of the protector ______________________________

____

4. In the line starter the letters OL stand for ______________________

____

5. The purpose of an OL switch is ______________________________

____

6. The load terminals in the line starter are labeled __________, ________ and

____

7. The power terminals in the line starter are labeled __________, __________

and ____________

8. The main power terminals in the defrost timer are __________ and __________

9. If the power company furnishes 230V to the disconnect switch, the voltage at terminals 3 and X in the defrost timer will be ______________________

10. The path for current flow to the defrost heaters will be completed through terminals ________________ and ____________________

11. When the defrost heaters are energized, what happens to the evaporator fans?

____

12. The defrost cycle can be terminated by ______________ or ____________

13. The single-pole double-throw thermostat controls ____________ and ____________

14. Explain how the unit cycles off when the contacts in the temperature control open.

____

____

____

15. On an evaporative cooled condenser, what controls the head pressure? __________

____

16. Does the water pump cycle? ____

17. Why? ____

18. The coil in the line starter will not energize. List the possibilities that could cause this trouble.

____

____

____

19. The meter reads 230V at terminals 1 and 2 on the solenoid valve, but the valve

will not energize. Why? ____

20. Evaporator fan number 2 is running, but number 1 is not. Why? ______________

____

Checked by ________________________
Instructor

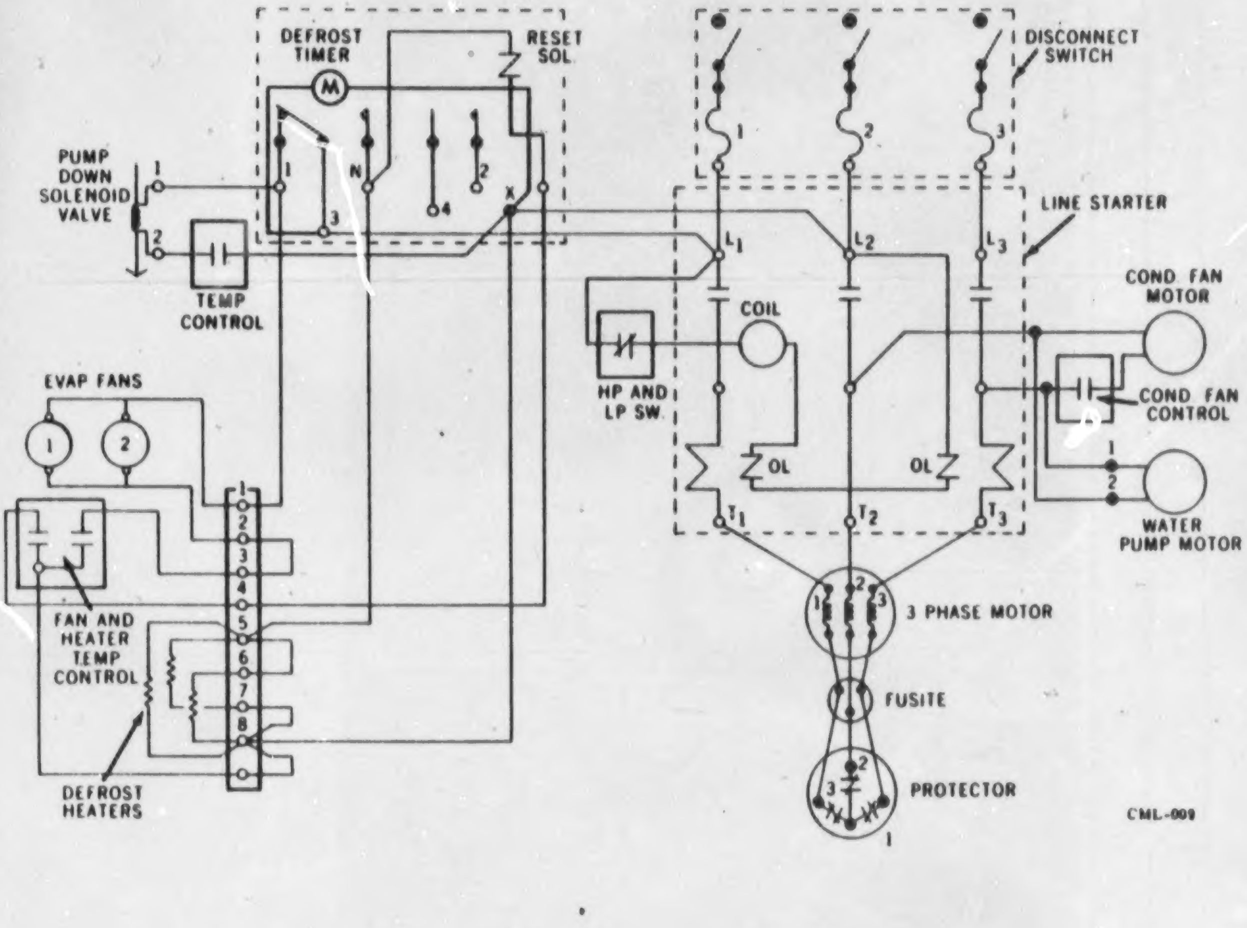
DEFROST TIMER
M
RESET SOL.
1
N
2
3
4
X
PUMP DOWN SOLENOID VALVE
1
2
TEMP CONTROL
EVAP FANS
1
2
FAN AND HEATER TEMP CONTROL
DEFROST HEATERS
1
2
3
4
5
6
7
8
DISCONNECT SWITCH
1
2
3
LINE STARTER
L1
L2
L3
COIL
HP AND LP SW.
OL
OL
T1
T2
T3
COND. FAN MOTOR
COND. FAN CONTROL
1
2
WATER PUMP MOTOR
3 PHASE MOTOR
1
2
3
FUSITE
PROTECTOR
2
3
1
CML-009

Figure 1. Walk-In Freezer Electrical System

350

WATER COOLER MAINTENANCE

OBJECTIVE:

To be able to locate, identify and give purpose of the major components of water coolers; to trace the flow of water, refrigerant and electrical current through the system; and to troubleshoot and make necessary adjustments.

1. Go to the cutaway water cooler and locate the following items:

   a. Water inlet connection

   b. Compressor

   c. Suction line

   d. Evaporator

   e. Refrigerant control

   f. Water tank

   g. Bubbler

   h. Water-to-water heat exchanger

   i. Waste water connection

   j. Condenser

   k. Condenser motor and fan

   l. Thermostat

2. Trace the flow of water, refrigerant and electrical current through the system.

3. Go to a bubbler type water cooler and complete the following.

   a. Remove the front panels.

   b. What type of compressor is used? ________________________

   c. What type of starting relay is used? ________________________

   d. Does this unit have a freezestat? ________________________

   e. What type of condenser is used? ________________________

4. Go to the water cooler assigned to you and complete the following maintenance and service procedures.

   CAUTION: Unplug the service cord before cleaning the unit.

   a. Check condensing unit for cleanliness. Wipe the entire condensing unit with a clean rag.

   b. Plug in service cord and allow unit to operate until it cuts out on the thermostatic motor control.

   c. Check temperature of cooled water by placing a hand thermometer in the outlet water stream for about 30 to 40 seconds.

      NOTE: The desired temperature of cooled water is 50° to 55°F.

   d. If the water temperature is not between 50° to 55°F, remove the front cover and adjust the thermostat to maintain the desired temperature.

   e. Check bubbler adjustment and readjust if necessary.

      NOTE: Water stream should strike drainboard about 1 inch from drain outlet.

   f. Check all waterline connections and refrigerant line connections for leaks. Make repairs if necessary.

   g. To back-flush water storage tank, observe the following procedures:

      (1) Turn off water.

      (2) Remove inlet water line from inlet connection.

      (3) Connect inlet water line to remote connection.

         NOTE: If there is no remote connection, you must remove the bubbler and connect the inlet water to the bubbler connection.

      (4) Place bucket under inlet to catch waste water.

      (5) Turn on water and flush tank.

      (6) Replace all lines to their original position.

   h. Operate the unit and check for normal operation.

Checked by ______________________________
Instructor

1. Complete the wiring diagram of a water cooler.

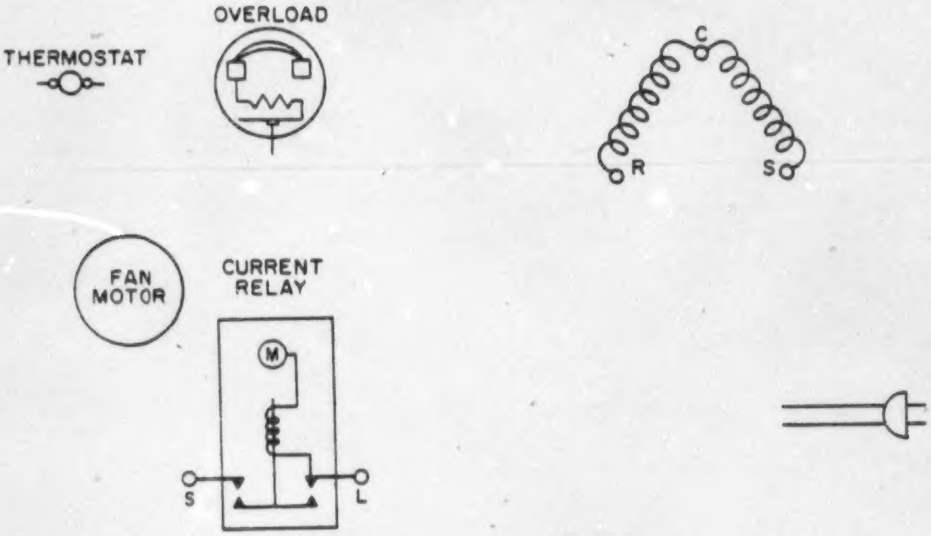
OVERLOAD
THERMOSTAT
C
R
S
FAN MOTOR
CURRENT RELAY
M
S
L

Figure 2

REPAIR AND MAINTENANCE OF REACH-IN BOXES, DISPLAY CASES, AND ICE CREAM CABINETS

OBJECTIVE:

To locate and identify the major components of commercial units, and operate and maintain commercial units.

NOTE TO INSTRUCTOR: Divide the class into three groups and have the students work on each item in rotation.

REACH-IN

1. Locate and give the main purpose of each of the following components:

   a. Compressor ______________________________

   b. Condenser ______________________________

   c. Receiver ______________________________

   d. Sight glass ______________________________

   e. Expansion valve ______________________________

   f. Evaporator ______________________________

   g. Starting relay ______________________________

   h. Thermostat ______________________________

2. Name three places where reach-in boxes are used.

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. Type and make of condensing unit

   a. Type ______________________________

   b. Manufacturer ______________________________

4. Type of refrigerant ______________________________

5. Type of refrigerant control ______________________________

6. Type of starting relay ______________________________

7. Does this unit require a starting capacitor? ______________________________

8. Trace the flow of the refrigerant and air through the system.

9. Check the condition of all door seals.

10. Check for correct adjustment of door latches and hinges. Readjust if necessary.

DISPLAY CASES AND ICE CREAM CABINETS

1. Go to the display case or ice cream cabinet and complete the following.

2. Locate and give the main purpose of each of the following components:

   a. Compressor ______________________________

   b. Condenser ______________________________

   c. Receiver ______________________________

   d. Drier ______________________________

   e. Sight glass ______________________________

   f. Evaporator ______________________________

   g. Expansion valve ______________________________

   h. Evaporator fan ______________________________

   i. Suction line filter ______________________________

   j. Starting relay ______________________________

3. Trace the flow of the refrigerant and air through the system.

4. Check all fans for freedom of rotation; clean the blades if necessary.

5. Check the condenser and clean if necessary.

6. List the four things you must check when replacing a condenser fan motor.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

7. The average box temperature should be ______________ °F.

Procedures:

Accomplish all preoperational checks listed below prior to operation of the trainers and observe the listed procedures closely during all operations.

PREOPERATIONAL CHECKLIST

1. Remove all jewelry before working on trainers.
2. Main power supply off (if reach-in box, unplug cord).
3. If working on ice cream cabinet, pull out the condensing unit and check for frayed wiring and loose connections.
4. If working on reach-in box, remove condensing unit cover and check for frayed wiring and loose connections.
5. Check tubing for indications of leaks.
6. Check condenser and evaporator fans for freedom of rotation.
7. Check condenser and evaporator fin condition. Check compressor oil level (display case).

OPERATIONAL and SAFETY CHECKLIST

1. Wear goggles and install gages.
2. Gage service valves.
3. Plug in the power cord or turn power supply on and operate the unit.
4. Record gage readings: A. High ______________ B. Low ______________.
5. Check refrigerant charge. Charge the unit if necessary.
6. Observe the operation of the unit.
7. Do not lay tools on the floor.

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POSTOPERATIONAL CHECK

1. Unplug the power cord or turn power supply off.
2. Back seat service valves.
3. Remove manifold gages.
4. Push the condensing unit back in place if ice cream cabinet.
5. Replace condensing unit cover if reach-in refrigerator.
6. Clean up the area and replace tools.
7. Have the instructor check your work.

Checked by ______________________________
Instructor

DISPLAY CASE ELECTRICAL SYSTEM

Draw lines to complete the electrical diagram of the display case electrical system.

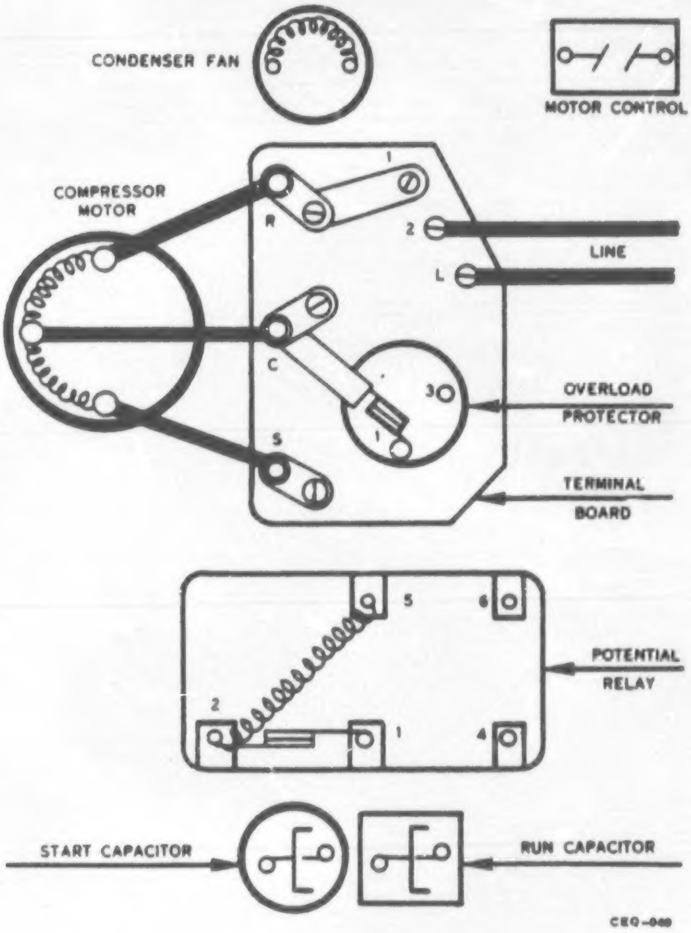
CONDENSER FAN
MOTOR CONTROL
COMPRESSOR MOTOR
1
R
2
L
LINE
C
3
1
OVERLOAD PROTECTOR
S
TERMINAL BOARD
5
6
2
1
4
POTENTIAL RELAY
START CAPACITOR
RUN CAPACITOR
CEQ-040

Figure 3

INSTALLATION OF COMMERCIAL UNITS

List the steps for installing commercial refrigeration units in the spaces below.

____

____

____

____

____

____

____

ADJUSTING MOTOR CONTROLS ON COMMERCIAL REFRIGERATION UNITS

OBJECTIVE:

To be able to adjust motor controls to maintain a given temperature in a commercial refrigeration unit.

NOTE: There are several different manufacturers producing both pressure and temperature motor controls that are used on various types of commercial refrigeration units. If you understand the principles of operation and adjustment of one manufacturer's controls, you can figure out any of the others very easily.

PROBLEMS:

Adjust the motor control to maintain a temperature of 15° to 25° in a walk-in box (assume an evaporator T. D. of 10° unless otherwise stated).

1. Draw a condition chart as illustrated in Figure 4.

	Box Temp	Evap Temp	Suction Pressure
Cut-in			
Cut-out			

Figure 4. Condition Chart

2. Place the required cut-in and cut-out temperatures in their respective places. In this case, the cut-out is 15 and the cut-in is 25.

   NOTE: At cut-in, the evaporator temperature and box temperature will be the same (the evaporator fan continues to operate and the compressor is off).

3. Place 25° under evaporator temperature.

   NOTE: At cut-out, the evaporator temperature is 10° less than the box temperature. This is due to the fact that we are using a 10° T. D. evaporator.

4. Place 5° under evaporator temperature.

5. Use your pressure-temperature relationship chart and look up the refrigerant (R-12) pressures for 25° and 5°. In this case, it is 24.6 and 11.7, respectively.

6. Place 24.6 and 11.7 in the condition chart.

7. Subtract 11.7 from 24.6; this gives you the pressure differential. It is 12.9.

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NOTE: Up to this time, we have not considered the type or manufacturer of the motor control being used. With the information available in the condition chart, we can adjust any type of motor control to maintain the required temperatures.

8. Fill in the blanks for the following controls.

PENN

	Box Temp	Evap Temp	Suction Pressure
Cut-in			
Cut-out			

RANCO

	Box Temp	Evap Temp	Suction Pressure
Cut-in			
Differential			

9. Have the instructor check your work.

Checked by ______________________
Instructor

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FAMILIARIZATION AND OPERATION OF ICEMAKERS

OBJECTIVE:

To be able to locate and identify the major components and state principles of operation of the icemaker.

1. Turn the icemaker off.
2. Remove the top and access panels.
3. Locate and identify the following components:
    a. Compressor
    b. Oil separator
    c. Condenser
    d. Condenser fan
    e. Receiver
    f. Hot gas solenoid valve
    g. Liquid line
    h. Expansion valve
    i. Evaporator
    j. Icebreaker fingers
    k. Suction line
    l. Water reservoir
    m. Water pressure switch
    n. Waterflow switch
    o. Two-speed motor control
    p. Low-pressure safety control
    q. Water pump
    r. On-off switch
    s. Drain line

- t. Float valve
- u. Fresh water strainer
- v. Waterline
- w. Bin thermostat

4. Explain the main purpose of each of the above components.
5. Start at the water strainer and trace the flow of the water through the system during the freezing and harvest cycle.
6. Start at the compressor and trace the flow of the refrigerant through the system during the freezing cycle.
7. Start at the compressor and trace the flow of the refrigerant during the harvest cycle.

Procedure:

Accomplish all preoperational checks listed below prior to operation of the trainers and observe the listed procedures closely during all operations.

PREOPERATIONAL CHECKS:

1. Remove all jewelry prior to working on trainer
2. Breaker switch in off position
3. Master switch in off position
4. Check for frayed or loose wiring
5. Check tubing for evidence of leaks
6. Check condenser fin condition
7. Check condenser fan for freedom of rotation.

OPERATIONAL and SAFETY CHECK

1. Wear goggles to install gages
2. Gage service valves
3. DO NOT LAY TOOLS ON FLOOR
4. Breaker switch on
5. Master switch on
6. Observe pressures during freezing cycle

7. Record the pressures just before the harvest cycle begins:

   (a) High side ________________

   (b) Low side ________________

8. Record the pressures at end of harvest cycle

POSTOPERATIONAL CHECK (shutdown)

1. Breaker switch off
2. Back seat service valves
3. Remove manifold gage assembly
4. Replace all panels
5. Breaker switch off

Checked by: ____________________________
(Instructor)

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